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A Taxonomy for Predicting Team and Collective Task Performance Change

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for

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A TAXONOMY FOR PREDICTING TEAM AND COLLECTIVE TASK PERFORMANCE CHANGE

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A TAXONOMY FOR PREDICTING TEAM AND COLLECTIVE TASK PERFORMANCE CHANGE

INTRODUCTION

Teams are established to perform functions that cannot be done by one person. Such functions are amenable to a division of labor among persons and require some type of coordinated effort among team members in order that the team task be completed (Hall and Rizzo, 1975; Roth, Hritz, and Lewis, 1982; Dieterly, 1978). The coordination of effort among team members is generally referred to as **teamwork**. Teams, and the need for teamwork, are ubiquitous. One domain in which teams and their performance is particularly important is the military. Because of the complexity and scope of the missions and tasks assigned to military organizations, teams are formally organized at practically every level, from weapons crews to Service general staffs. Ensuring that teams at all levels can perform their tasks competently (i.e., ensuring **collective task performance**) is a major goal of military training. A term commonly used to refer to training for teams in the military context is **collective training**.

For all the importance of teams and collective performance to the military (and in many other contexts as well), relatively little useful research has taken place to gain a comprehensive understanding of team behavior and performance and factors that work to establish and maintain real-world team performance. A large body of research has been performed exploring the behavior of small groups—some of which meet the criteria to be considered teams (for useful reviews, see Dyer, 1984; Freeberg and Rock, 1987; and Denson, 1981). However, this research is best characterized as piecemeal in nature.

A wide variety of hypotheses have been proposed and investigated concerning the influences on team performance of team task characteristics, team composition, team size, team member characteristics, cohesion in teams and groups, and a host of other factors. A broad spectrum of team tasks (the majority of them contrived, rather than real-world tasks) have been used in investigations to determine the influences of these factors. The findings of this body of research are at best equivocal with respect to making predictions about the performance of teams and effective ways of training for team performance (Dyer, 1984). Perhaps the strongest general statement that can be made at this point is that some factors have been identified that can be loosely related to team performance. No consensus exists with respect to operational definitions of variables, metrics, or specific relationships of the factors to team performance. Efforts (e.g., Freeberg and Rock, 1987) to unify the existing empirical data have met with only limited success.

A related shortcoming of this body of research is that there has emerged no theory of team performance and team behavior to provide a basis for programmatic research. While there have been many attempts to characterize the variety of behaviors demonstrated by teams in performing team tasks (Lewis, Hritz, and Roth, 1982a, 1982b; Dyer, Tremble, and Finley, 1980; Nieva, Fleishman, and Reick, 1978), these have not led to consensus. Unified concepts that can lead the researcher to formulate testable hypotheses about the effects of factors on team behavior and performance have not been adopted. Partly because of the lack of any theory about team behavior and performance, little research into practical, real-world means of shaping team performance and influencing the development and sustainment of teamwork has taken place. The work reported on in this report grew out of a need for methods to predict team performance in the real world in the context of developing a method for scheduling Army collective training.

The Present Research

The ultimate objective of this research is to develop a method for identifying when training should be conducted for collective tasks performed by small Army units (Platoons, Squads, and Crews). Such methods exist for **individual** tasks (Rose, et. al., 1980), but none have yet been developed for collective tasks.

Rationale

Why is a method needed for identifying requirements to conduct collective task training? There are several major reasons.

Resources are Limited. Collective task training can be costly in terms of resources. Depending on the team type and the task, major items of equipment (i.e., tanks, cannons, wheeled vehicles, etc.) may be needed to support training. Using these kinds of resources not only causes wear and tear on the equipment, it also consumes fuel, ammunition, and other commodities, as well as scarce training time. Therefore, collective training should only be conducted when it can be genuinely justified.

Skills Decay. The skills and knowledge associated with collective task performance deteriorate when they are not practiced for periods of time—a process often referred to as skill decay. While practically nothing is known about the retention of collective task skills and knowledge **per se** (Farr, 1986), a good deal is known about the retention of individual task skills and knowledge (Rose, et. al., 1980). Since many of the skills and knowledge that support collective task performance are related to individual task-supporting skills and knowledge, we project that similar changes in performance without practice (i.e., due to skill decay) will occur with collective tasks.

The focus here is however on **long-term** retention of knowledge and skills—over periods of weeks and months, as opposed to retention over shorter periods. Under existing resource constraints, as well as due to other factors, it is not feasible for Army units to train collective tasks with great frequency. Thus, there are periods of time when collective training for particular teams or tasks simply does not take place. In isolated extreme cases (e.g., Roth, 1990), units are reported to have gone as long as a year without practicing collective tasks.

Farr (1986), in reviewing the literature on long-term retention, concluded:

> **...as the retention period gets longer without the use of the learned skill or knowledge, decay tends to increase...there is a classic curve of forgetting: the absolute amount of decay increases with time, whereas the apparent rate of forgetting declines over time. However,...it is evident that the amount of forgetting during the retention interval is very sensitive to the type of task, the level of original learning, and the conditions and strategies of instruction. For example, a continuous motor task will be more resistant to decay, over any time period, than a rote memory task. Similarly, a highly overlearned skill will be retained longer than a barely mastered one. Although these conclusions may seem banal and obvious, they represent essentially all we know about how the length of the retention period affects long-term memory** (p. 89; this author's emphasis).

What this means from our viewpoint in this report is simply that we think of skill decay as a **qualitative** function of time. We cannot yet quantify skill decay for teams in terms of the amount of performance proficiency lost over a given period of time. That will be one result of this research as a whole.

Team Membership Changes. Skills and knowledge may also be lost due to changes in team membership resulting from turnover (absolute changes in membership) or turbulence (changes in the positions occupied by team members). Túrnover and turbulence are facts of life for military teams. Recent data (ATI, 1989; Roth, 1990) suggest that turnover in some Army units is sometimes as high as 50 percent over a three-month period. While turbulence is difficult of itself to measure (ATI, 1989), high levels of turnover inevitably result in some level of turbulence as key positions in team organizations are filled.

Both turnover and turbulence have been found to affect team performance. Higher levels of turbulence (Eaton and Neff, 1978) and turnover (Forgays and Levy, 1957; Morgan, Coates, Alluisi, and Kirby, 1978) have been shown to result in poorer team performance. Turnover in leader positions (Trow, 1964; Ziller, 1963) has been associated with larger effects on team performance than turnover in unspecialized members of small groups. Thus, **stability** of team membership is a major factor to be considered.

Summary. The foregoing establishes that there is a need for to predict when collective tasks should be trained. Skills and knowledge decay without practice, and team membership changes cause additional loss of skills and knowledge needed to support a team's collective task performance. However, due to the resource cost of training collective tasks, training should only take place when necessary to establish or re-establish the needed skills and knowledge for a team.

Context of This Effort Within the Research at Large

This report is the result of one task performed in the course of developing a means for predicting the need for collective task training. To make such predictions, the relationships among changes in team performance, skill decay, and team membership change must be established. This means that data from which to identify these relationships must be gathered. However, a large number of collective tasks is typically performed by Army team types (50 to 60 is not unusual in teams in the combat arms branches). Obtaining data on such a large body of tasks was deemed impossible. The approach of sampling from the pool of collective tasks for team types was adopted.

Lacking extant theory to provide a basis for selecting a representative sample of team tasks, a supporting rationale for task selection had to be developed. This rationale is a taxonomy of attributes of teams and team tasks, presented later in the report. Multiple attributes are necessary in each taxon, since there are many aspects to the differences among teams and collective tasks.

A model of the determinants of team performance was used to develop the taxonomy. Through identifying that team performance depends ultimately on the contrast between: (a) the skills and knowledge required to perform a team task; and (b) the skills and knowledge currently available within the team, this model provided a conceptual basis for selecting attributes for inclusion in the taxonomy.

Since the model of the determinants of team performance may also be of value to others studying with team performance, it is presented in the next subsection.

A Model of the Determinants of Team Performance

In a broad sense, the performance of a team on a particular collective task can be thought of as the team's ability to meet the performance requirements of the task. This means, again in a broad sense, that one means of predicting team performance is to identify indicants of likely deficits or shortfalls in the performance capability of a team. For our purposes, it is desirable to reflect these shortfalls in terms of the two team performance predictor variables—forgetting and membership change. However, other characteristics or factors influence the way in which these predictors act to prevent team performance from attaining its potential maximum. To identify these factors, it is useful to consider the ultimate determinants of team performance.

Bass (1982) developed a generic model of the determinants of team performance. Bass' model identified the sources of the performance demands of a team task, and how these demands can be compared with the ability of the team to meet the demands. In essence, Bass described less than adequate team performance as a deficit in the skills and knowledge available to the team, compared to those needed to perform to standard.

Figure 1 shows a model of team performance determinants adapted from the one Bass (1982) developed. The adaptations to the original come largely from the fact that it is possible in this work to specify particular military teams as a focus of consideration (Bass included less formally organized teams and less well-structured tasks in his model development).

The model, as depicted in Figure 1, illustrates the factors that determine what the performance of a team will be in a specific instance of doing the task under specific conditions. There are three sources of team performance determinants included in Figure 1. They are:

1. The determinants of generic **performance demands** for a team task, in terms of the skills and knowledge required (in the abstract) to perform the task. These are indicated by narrow solid flow lines in the Figure.

2. The determinants of the **present capability of a specific team** to bring the needed skills and knowledge to performing a team task. These are indicated by broad solid flow lines in the Figure.

3. Variables that influence the skills and knowledge required as well as the skills and knowledge available to a team **for a specific performance of the task.** These are depicted by dashed flow lines in the Figure.

The following paragraphs discuss performance demand determinants, determinants of a team's capability to perform, and the influence of situational factors on the contrast of the two. In this discussion, reference is made to the lettered shapes, or nodes, in Figure 1 and the numbered flow lines joining them, to illustrate specific patterns of determinacy within the model. The significance of the different shapes used for the nodes in the model will be discussed later.

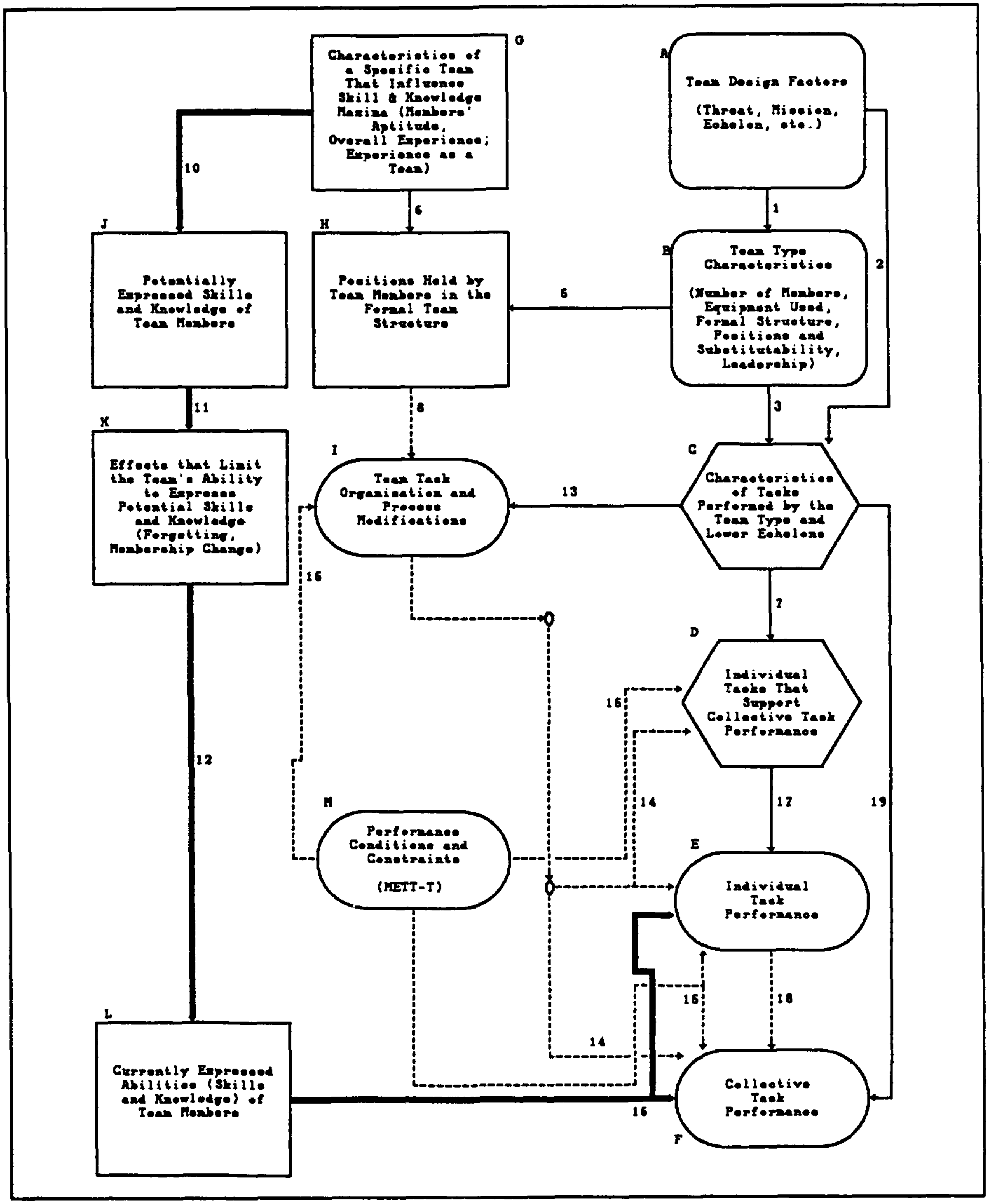

Figure 1. A model of the determinants of collective task performance

Determinants of Team Task Performance Demand

We begin discussion of the model by identifying the sources of demands for skills and knowledge to perform a team task, in the abstract. This is specifically distinguished from a specific performance of the task, because situational factors that change the demands are dealt with later in the discussion.

Referring to Figure 1, the sources of skill and knowledge demand for performing a team task can be ultimately traced to the factors that influenced the design of the team and the selection of the team tasks that the team performs. This is depicted by node A at the upper right-hand corner of the Figure. For military teams, team design and task selection are based on an analysis of the threat(s) the team will face in combat, the force required to defeat the threat, and the missions that will be performed by the team.

Evaluation of the team design factors leads to the specification of two critical sets of attributes of a team: the characteristics of the team type (via flow line 1); and the characteristics of tasks that are performed by the team type (and sub-teams or lower echelons that may be organized within the team type; via flow line 2). These sets of attributes are important factors that influence the action of the primary predictors on team performance (see the taxonomy later in this report).

The characteristics of the team tasks performed (node C) in turn specify the constellation of individual tasks must be performed in the course of performing each team task (node D, via flow line 7). Typically, each team task calls for performance of a different constellation of individual tasks; but the individual task constellations can overlap from one team task to another. For example, an Infantryman will probably have cause to use cover and concealment (one individual task) in many of the team tasks in which he is involved.

Team type characteristics (node B in Figure 1) include the formal structure of the team, or the permanently defined positions that can be occupied by team members and leaders. This can interact with the characteristics of the personnel that make up actual teams, influencing the assignment of individuals to positions in the actual team. This is an indirect influence on the capability of the team in terms of the skills and knowledge available to support a particular task performance. This is depicted in Figure 1 by flow line 5 from node B to node H.

The collective tasks identified as a result of the team design process should be thought of as generic **templates** for the performance of the task. Collective task descriptions embody (even if only implicitly) generic skill and knowledge requirements for both the individual task constellation required to perform the team task, and teamwork-related components (including task-organization requirements) of the team task. These are subject to modification, depending on the conditions under which a task is performed. This is depicted in Figure 1 by flow line 13 from node C to node I.

In summary, the skill and knowledge demands of a team task derive from the attributes of the team type and the team tasks to be performed, and the component individual tasks required to perform the team tasks. Thus, the skills and knowledge required to perform a team task can be thought of as being determined, in the broadest scope, by the team design and task selection process. But, the required skills and knowledge can be modified by situational factors, as we discuss shortly. Before turning to this, however, we trace the determinants of the skills and knowledge brought to task performance by a specific team.

Determinants of Available Team Skills and Knowledge

The maximum potential for expressing skills and knowledge in the course of a team task performance is ultimately determined by some aggregate of attributes of the current team members. This is depicted in Figure 1 by node G at the upper center of the Figure, flow line 10, and node K. The attributes of interest include team members' aptitude and general experience in their job specialties, and their experience as members of the specific team of interest (i.e., 1st Platoon, C Company). Members' aptitude and general experience also influence the positions to which they are assigned in the formal team structure (flow line 6 to node H). The assignments of people to positions in the formal team structure may also influence the way in which the team task-organizes to perform particular team tasks (flow line 8 from node H to node I).

Factors already mentioned—skill decay and personnel change—reduce the potential of the team to express skills and knowledge from the maximum to some other value. This is depicted by the flow from node J through flow line 11 to node K, and on to node L via flow line 12, in Figure 1. So, at the particular time a team task is to be performed, the team has available some constellation of skills and knowledge to support task performance: probably less than a theoretical maximum value. The application of the available skills and knowledge in task performance is represented in Figure 1 by the flow lines labeled 16 from node L to nodes E and F.

Factors Modifying Performance Demands and Team Performance Capability

Any real-world team performance takes place in a context that may alter the skills and knowledge required to perform the task successfully. For Army collective tasks, relevant contextual conditions are summarized by the abbreviation **METT-T**, which stands for Mission, Enemy situation, Troops (available), Terrain (and weather), and Time available (for planning the task). Performance conditions and associated constraints are represented by node M in Figure 1 and the flow lines labeled 15, leading from it. These conditions can directly influence the way the team organizes to perform the task (node I), the specific individual tasks required in team task performance (node D), and can also influence the successful performance of component individual tasks and the collective task (nodes E and F). In addition, modifications in the task-organization and possibly the process of performing the collective task (as a result of the existing conditions) can further modify the constellation of individual tasks required, as well as influencing individual and collective task performance (flow lines labeled 14).

Relationship of the Model to the Taxonomy

Earlier, it was mentioned that the shapes of the nodes in Figure 1 have significance. The significance of the various shapes used is that they indicate groupings of factors that determine team performance. This was one key to developing the taxonomy presented below. The round-cornered nodes at the upper right of the Figure indicate factors inherent in the design of the **team type** under consideration. Hexagonal shapes below these depict factors associated with the **team tasks** that the team performs. These two groupings of factors are **relatively stable characteristics** that determine the skill and knowledge demands of team task performance, in the abstract.

The rectangular shapes at the top and on the left of the Figure indicate attributes of **particular teams** that influence the skills and knowledge available to support team performance. Finally, the oval-shaped nodes at the center and lower right indicate the **influence of conditions or situational factors** on both the demands for skills and knowledge and the team's capability

to meet those demands in a particular instance of performing a task. These groupings represent **variable elements influencing team performance.**

This had influence on the development of the taxonomy. It was decided that the attributes concerned with relatively stable characteristics that determine team performance should be included in the taxonomy. The specific-team and situational factors are not appropriate to a taxonomy to support selection of representative tasks. Therefore, only two taxa were developed for the purpose of task selection: the first deals with attributes of team types; the second, with attributes of collective tasks performed by a team. A third taxon, dealing with characteristics of specific teams that can influence the skills and knowledge available to support team task performance, was also developed. This taxon may be useful in making practical decisions about which specific teams should receive training, in conjunction with the predictive method that is the ultimate goal of this work. The fourth grouping of influences on team task performance—situational factors—cannot be investigated as part of this work. While these factors are undoubtedly of importance in determining team performance, it is beyond the scope of this research to gather the extremely large body of data that would be needed to programmatically explore the effects of these factors.

The model also provided a basis for evaluating attributes for inclusion in the taxonomy. The model deals conceptually in terms of the skills and knowledge required to perform collective tasks. This gave a foundation for assessing candidate attributes. A likely relationship between changes in an attribute, and changes in the skills and knowledge available to support team performance, suggested that the attribute be included in the taxonomy. Changes in skill and knowledge as functions of both skill decay and team membership change were evaluated in this way for each candidate attribute. Attributes that appeared to have logical relationships to changes in the skills and knowledge available to support team performance were included in the taxonomy. The attributes considered were drawn from the literature on teams and team performance, or were defined from studying the characteristics of military collective tasks as documented in Army Training and Evaluation Program (ARTEP) Mission Training Plans (AMTPs). The logic for each attribute is discussed in presentation of the taxonomy.

A TAXONOMY FOR PREDICTING TEAM AND COLLECTIVE TASK SENSITIVITY TO PERFORMANCE CHANGE

This section of the report presents the taxonomy developed to provide a rationale for collective task selection in this research. Use of the taxonomy will provide a basis for examining the relative sensitivity of teams and tasks to performance change resulting from skill decay and team membership change. The attributes making up each of the three taxa are described in separate subsections. Indications of the sources from which the attributes were identified, and the rationale for including each attribute, are provided in the description that follows. The end result of application of this taxonomy is the selection of a sample of tasks on which data are to be gathered to support developing the collective task performance prediction method. Preliminary application of the taxonomy, as well as some preliminary work on validation of the taxonomy, are described in the following section.

A taxonomy (Fleishman and Quaintance, 1984) is ideally discrete in its classifications, hierarchial, and mutually exclusive and exhaustive across the range of phenomena that are represented by the taxonomy. This taxonomy meets only two of these three criteria. By its nature, performance is a continuous, rather than a discrete variable. Therefore, the classifications of teams and collective tasks using the taxonomy are continua, rather than discrete categories.

Taxon 1--Team Type Sensitivity to Performance Change

This taxon represents the top hierarchial level of the taxonomy. It provides a means for evaluating team types (e.g., Light Infantry Squads, Armor Platoons) as to their relative sensitivity to performance change as a result of skill decay and team membership change. The location of a team type on the continuum of sensitivity to performance change is established by evaluating seven team-type attributes, discussed below. Judgments about the contributions of the factors on the effects of skill decay and team membership change are then combined to identify where a team type falls on the sensitivity continuum relative to other team types.

Although, as shown in the next section, applying this taxon results in a numeric score for a team type, the level of measurement on this continuum is, at best, ordinal. That is, it enables a comparison of team types on sensitivity to performance change through predicting that team types will be more versus less sensitive—but cannot speak to the magnitude of the difference. It is a means of identifying team types that will show greater or lesser impacts of skill decay and performance change as a result of the inherent design characteristics of the team types. The attributes of this taxon discussed below are the design characteristics identified as important to making this distinction.

Team types vary on a multitude of attributes, including number of members (size), type of formal or informal organizational structures or communication patterns, permanence, tasks performed by the team, the types of individual skills required for team task performance, technical support or equipment used in team performance, amount of experience working together, and numerous other dimensions (Dyer, 1984; Denson, 1981; Dyer, Trimble, and Finley, 1980).

The literature is ambiguous at best about direct influences of these attributes on team performance (Freeberg and Rock, 1987), particularly in real-world team tasks (Dyer, 1984). For example, the effects of team size on performance are confounded by the type of task the team performs, the organizational structure, and the distribution of required skills across members (Hackman, 1968, 1979; Steiner, 1972; Naylor and Dickinson, 1969). In the military, teams are organized and structured to perform specific functions at a given organizational level, and the minimum number of members is assigned to a team that will enable the team to perform the required functions (Dyer, 1984).

The seven attributes comprising this taxon are discussed in detail below. The discussion of each attribute includes a discussion of the hypothesized relationships that we propose between changes in the attribute and changes in the skills and knowledge available to support team performance.

Team Size (Number of Members)

This attribute obviously varies from team type to team type. For example, a tank crew has four members (commander, gunner, loader, driver), while a Light Infantry Squad has nine members (squad leader, two fire team leaders, and six soldiers with various equipment and positional responsibilities). The size of the team is hypothesized to be directly related to the amount that there is to learn and remember. In a larger team, each member must learn about the characteristics of, and his or her relationships with, a larger number of other positions than is the case with a smaller team. Also, in larger teams, there is the possibility of larger amounts of concurrent activity--up to the point where each member may act as a semi-independent sub-team. This means that there may be more to learn and remember about the individual member's relationships with other members or sub-teams in the context of performing a particular collective task. This hypothesis is somewhat borne out by Havron and McGrath's (1961) review of a number of studies on the relationships between the number of members in Infantry rifle squads and unit performance. With larger squads, performance deteriorated unless squad leaders (without subordinate leaders) exerted extraordinary effort to maintain performance. While this is not strictly analogous to our hypothesis (Havron and McGrath's findings could be more related to span of control of the leader), it definitely indicates a relationship between team size and team task performance, in military teams.

Since we propose that there is more to learn and remember in a larger team than a smaller team, we hypothesize that the effects of forgetting (i.e., decay without practice of a collective task) will be greater for larger teams than for smaller teams. That is, retention after a given interval will be poorer overall for larger teams than for smaller teams (see Figure 2). This is due to the larger absolute amount to be learned (and therefore, that can be forgotten). Larger teams should also be affected less by the same number of member changes, since a smaller overall proportion of the skills and knowledge required for collective task are lost when a member leaves the team. We so hypothesize, as shown in Figure 3. A measure for this variable is simply a count of the number of members in the team's formal organizational structure.

Formal Organizational Structure--Sub-teams

As we remarked at the beginning of the report, teams exist to perform tasks that cannot be done by one person. This means that there is either a formal or informal division of labor in the team as it performs its tasks (Dyer, 1984). In some teams, there is a more complex, hierarchial formal organizational structure than in other teams. For example, a Light Infantry

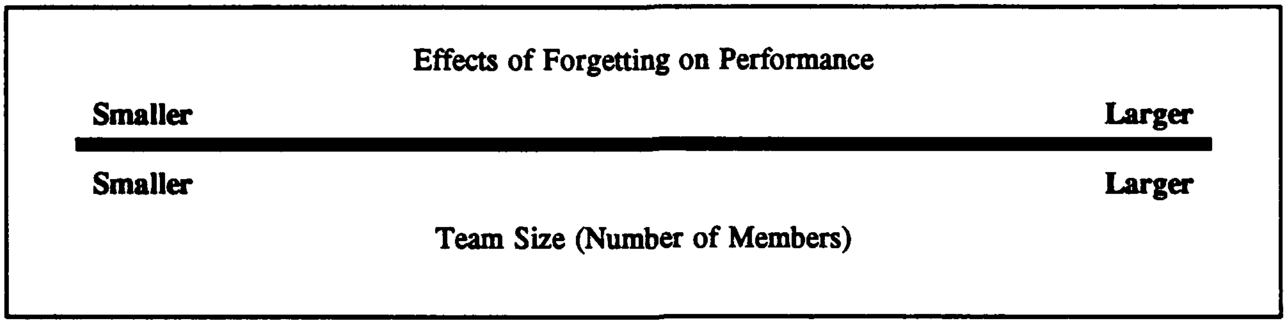

Figure 2. The relationship between team size and retention effects on team performance

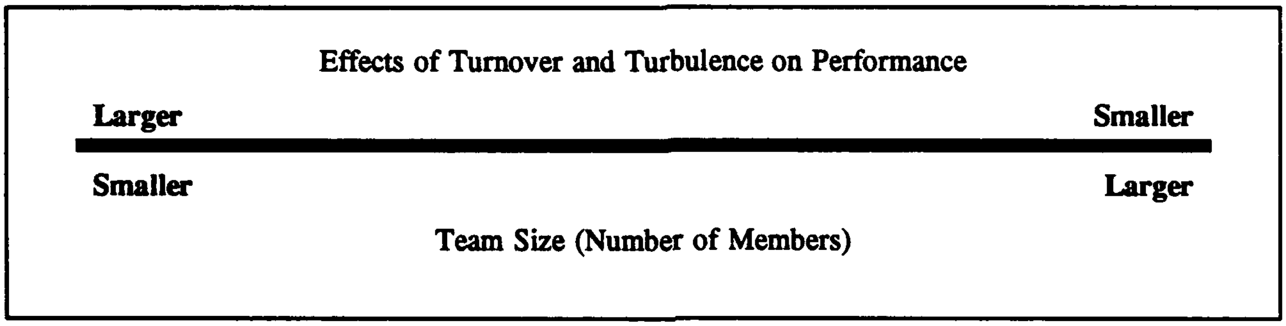

Figure 3. The relationship between team size and stability effects on team performance

Platoon contains three organizational echelons--the Platoon itself, three squads and a command element (itself containing the principal leaders, two two-man machine gun teams, and a radio operator), and two fire teams within each squad, each with its own designated leaders and member positions (Field Manual 7-70, Department of the Army, 1986). In contrast, an Armor Platoon contains only two organizational echelons--the Platoon and the four component crews (Field Circular 17-15, Department of the Army, 1986). Lower echelons of organization may be thought of as **sub-teams** of higher echelons. In fact, many sub-teams operate more or less independently from the remainder of the team in performing some collective tasks.

The number of sub-teams in a team's formal organizational structure may reflect the number of concurrent subtasks that a team can be required to perform in the course of a collective task. If this is the case, unless there is a great amount of position or role specialization in a team type, it suggests that the number of sub-teams is directly related to how much each team member may have to learn and remember to perform the team's collective tasks in the aggregate. This should bear a direct relationship to the amount the team at large must be able to know and do. Therefore, the existence of a larger number of sub-teams in a team's formal organizational structure suggests that there is a larger body of skills and knowledge required for collective task performance than is the case where there is a smaller number of sub-teams.

The literature does not provide evidence to confirm or deny a relationship between **formal** sub-team organizational structure and team performance. The issue seems not to have surfaced explicitly in earlier investigations, perhaps because many of these studies did not deal with real-world teams. Most studies of team or group structure in the literature have concentrated on communication patterns in synthetic groups (George and Dudek,

1974; Lanzetta and Roby, 1956), or on process issues such as methods of coordination between group members (e.g., George, Hoak, and Boutwell, 1963).

As a working hypothesis, we propose that the larger the number of sub-teams in a team type's formal organizational structure, the larger will be the loss of skills and knowledge via forgetting over a given period of time without collective training. Therefore, teams with larger numbers of sub-teams will experience more deterioration in performance over time if they do not train on team tasks. A larger number of sub-teams equates to a larger amount to learn and remember, and therefore a larger amount that can be forgotten.

With respect to the effects of turnover and turbulence, we propose a similar trend: the larger the number of sub-teams, the greater the effects of a given level of membership or role change. This is because of the distribution of sub-team-specific teamwork skills and knowledge across the membership of different sub-teams. The members of each sub-team must learn and remember the unique aspects of the relationships between their sub-team and other sub-teams. Where there are more sub-teams in a team's organization, there is more for each team member to learn and remember. Therefore, there is more impact on what must be learned and what is recalled by the team at large when membership changes occur. See Figure 4 for a graphic summary of these hypotheses.

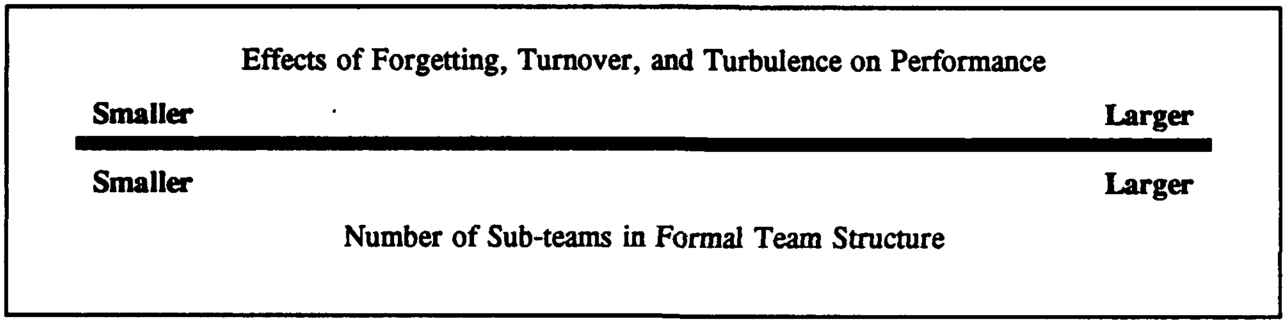

Figure 4. The relationship between number of sub-teams and retention and stability effects on team performance

A simple count of the number of sub-teams within a team (including all echelons, if there are multiple echelons of sub-teams) will be used as a measure for this variable.

Member Substitutability--Position Redundancy in the Team's Structure

In many teams, particularly where a formal sub-team organization exists, there are one or more positions that are the same (Dyer, Trimble, and Finley, 1980). For example, a Light Infantry platoon (on paper) contains three identical squads, each containing the same identical positions. The required qualifications for a position (e.g., automatic rifleman), and therefore the requisite skills and knowledge to perform in the position, are the same from one squad to another. Therefore, one grenadier is at least theoretically substitutable for another, discounting such issues as knowledge of Standard Operational Procedures (SOPs) that can differ from one squad to another. The fact that some team members should possess essentially identical skills and knowledge in order to fill their positions has implications for both of the primary team performance predictor variables.

With respect to retention, the people filling each of a collection of identical positions are likely to forget independently. That is, the loss of

knowledge and skills in one team member is unlikely to be identical to that of another. Stated another way, the decay functions for required skills and knowledge are different across individuals (Naylor and Briggs, 1961; Farr, 1986). This means that if one (e.g.) rifleman forgets some item of knowledge or experiences a loss of skill at some task, another rifleman probably will not have—at least to the same extent. Therefore, an individual who has not forgotten a critical item may be able to supply information to or otherwise cue another individual who has forgotten. Alternatively, a team member retaining a skill may be able to compensate for another's skill loss by substituting for him or her in performing a particular task. This means that the effects of changes in team membership on team performance may be somewhat mitigated when there is position redundancy in the team's structure.

Position redundancy may also ameliorate the effects of retention losses on the performance of the team as a whole. Under the hypothesis of independent forgetting, above, skills and knowledge will deteriorate differentially in each member of a team. The team as a whole may maintain most or all of the needed skills and knowledge for collective task performance—but perhaps not by all members who need the skills and knowledge. However, if some team members retain the needed skills and knowledge, these may be transferred rapidly to others in context of performing a collective task. This is a realistic speculation when one considers that military units doctrinally are supposed to plan and rehearse assigned missions. If forgetting has taken place on the part of some team members, the process of planning, preparation, and rehearsal of collective tasks in preparation for a mission provides an opportunity for such transfer or refreshing of skills and knowledge. It is well-established in the literature that refreshing forgotten knowledge or decayed skills requires fewer trials than initial learning (Schendel, Shields, and Katz, 1978).

While there is reason to believe that there is redundancy of skills and knowledge between different positions (many individual tasks are common for all soldiers in a Military Occupational Specialty, or MOS), there is also undoubtedly specialization for particular positions, as well. Therefore, only the substitution of one like position for another will be considered.

Our working hypotheses for this variable are as follows:

1. The greater the position redundancy in the formal organizational structure of a team type, the smaller will be the impact on collective task performance of turbulence and turnover; and

2. The greater the position redundancy in the formal organizational structure of a team type, the smaller will be the impact on team performance of skill and knowledge decay without practice. A graphic summary of these hypotheses is shown in Figure 5.

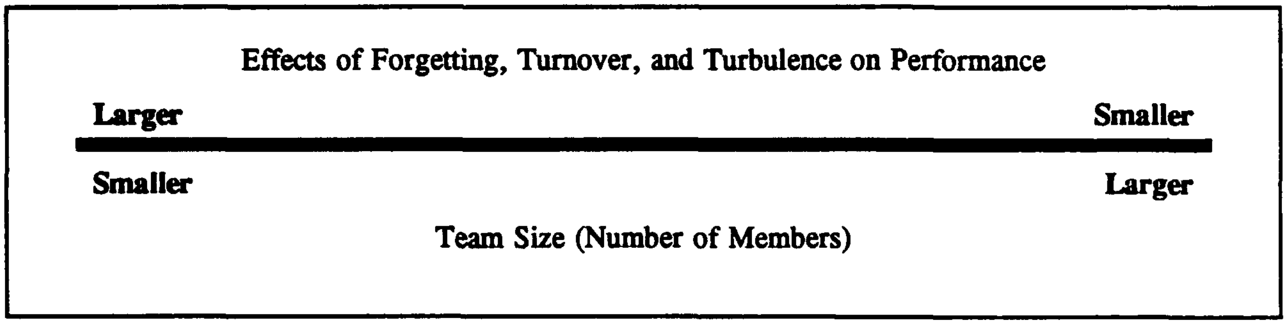

Figure 5. The relationship between position redundancy and retention and stability effects on team performance

To develop a measure for this variable, list the number of unique position titles in a team. Then, count the number of instances of each position in the organizational structure, and subtract one from the total for each position (a single member cannot substitute for his or her own position). Then, sum the results over all positions. This gives the position redundancy measure.

Equipment Used by the Team

Some military teams use many different items of equipment (including weapons), while others use only a few (Dyer, Trimble, and Finley, 1978). Many times, the type of equipment involved dictates the size and structure of a team (e.g., tank crews). Each different item of equipment imposes a requirement to learn (and remember) how to operate and maintain the item. While use of some equipment items may be position-specific (e.g., only radio-telephone operators operate and maintain radios in a Light Infantry platoon), other items may be ubiquitous (all Infantrymen learn to use and maintain the M16A2 rifle).

Clearly, the larger the number of equipment items used by a team, the more skills and knowledge are required to use and maintain the equipment items. Therefore, there is a direct relationship between the number of equipment items and the amount there is for the team at large to learn and remember. This should directly influence the amount forgotten per unit time, without practice—the more equipment a team has to learn to use and maintain, the more the team is likely to forget over a given interval. Team performance is hypothesized to be affected accordingly (see Figure 6).

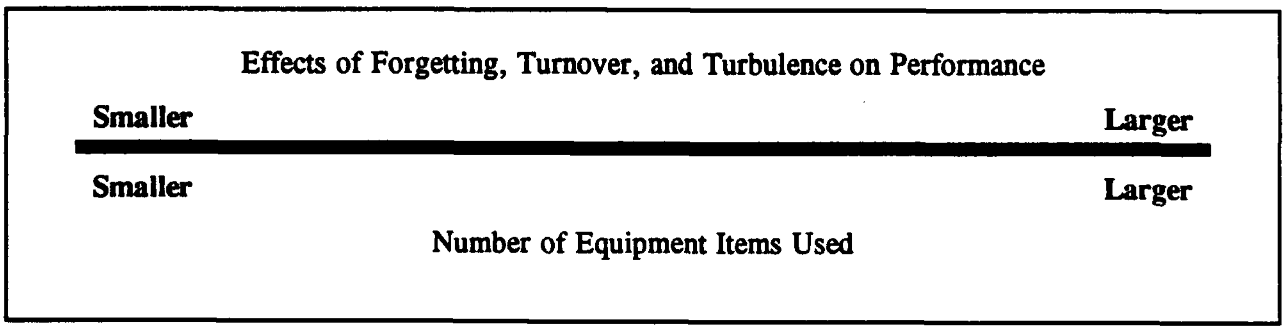

Figure 6. The relationship between equipment used by the team and retention and stability effects on team performance

Many equipment operation and maintenance skills are individual skills; the use of some items of equipment is specialized to particular positions in a team. This means that in some cases losing a team member also means losing the particular skills and knowledge needed to operate particular item(s) of equipment. Position changes (turbulence) within a team may also result in a temporary reduction in knowledge and skills available to support team performance, while a member learns to operate and maintain equipment associated with a new position. We hypothesize that the number of equipment items used by a team is related to the impact on team performance of turnover and turbulence—the more equipment, the larger the impact of membership or position changes on performance (Figure 6).

As we have noted, both the size of teams and the number of equipment items used by a team are variable. The two variables may not be independent, but the extent of the relationship between the two is not known in the general case. In view of this potential relationship, a measure for equipment items used by a team should consider the size of the team, as well. **Therefore, we will use the average number of major equipment items (e.g., tanks, weapons, radios, etc.) per team member as the measure for this factor.** Minor equipment items, such as clothing and load-bearing equipment, will be common to all team members and will not contribute to the information provided by this factor. Therefore, these will be discounted. Descriptions of the equipment used by a team type are found in the Tables of Organization and Equipment (TOE) for the team type.

Tasks Performed by the Team and Team Members

The requirement to perform any task imposes at least some learning and memory requirement on team members. In general, the larger the number of different tasks that may have to be performed, the larger the overall learning and memory requirement (other things being equal); although there is the likelihood that particular skills and knowledge will be useful in multiple tasks. Two distinct sets of tasks must be considered in evaluating the potential learning and memory requirements for a team type.

The first is the **collective tasks** that are performed by the team type. These impose a learning and memory requirement at some level on all members of the team. The larger the number of collective tasks performed by a team type, the more there will be for team members to learn and remember in order to be able to perform all of the collective tasks effectively. This relates directly to the impacts of forgetting on team performance—the more collective tasks for which specific skills and knowledge must be learned and remembered, the more that will be forgotten over a given retention interval. The same holds true for the effects of team membership change: the more tasks a team performs, the more each member has to learn and remember. Therefore, the effect of a given amount of turnover on team performance will increase with increases in the number of collective tasks performed. These hypotheses are summarized graphically in Figure 7.

Individual tasks must also be considered in evaluating the possible learning and memory requirements associated with a team type. The number of individual tasks required to support a team's performance on a collective task varies. However, the larger the number of individual tasks required to perform as a member of a given team type, the more there is overall to be learned and remembered by the members of teams of that type. Therefore, we hypothesize effects similar to those associated with variations in the number of collective tasks. The larger the number of individual tasks required of members of a team type, the greater will be the effects of forgetting and membership change on performance over a given retention interval (see Figure 7).

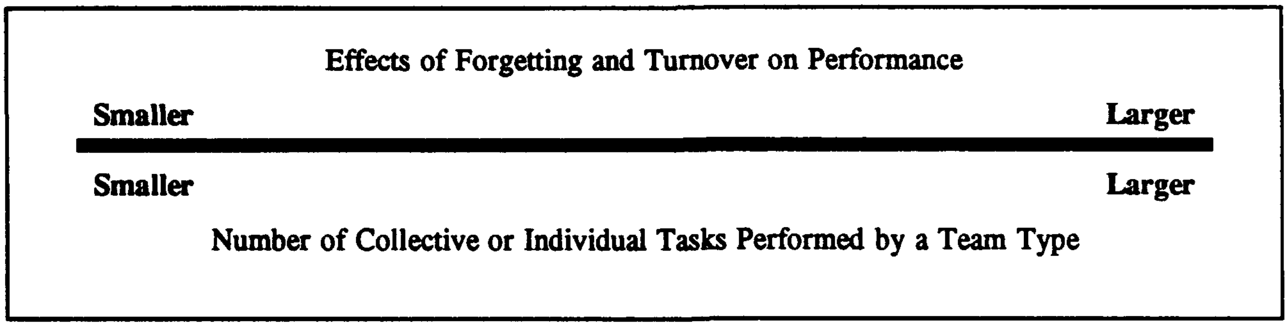

Figure 7. The relationship between the numbers of collective and individual tasks performed by a team and retention and stability effects on team performance

Measures for the number of tasks variables are derived from the task lists included in AMTPs for a team type, by counting the number of collective tasks included in the AMTP and the number of individual tasks that support the collective tasks. For individual tasks, only tasks specific to the Military Occupational Specialties (MOS) assigned to team members should be counted. Common tasks (those that soldiers in any MOS must be able to perform) should not be counted. These lists are presented in Chapter 2 of each AMTP.

Leadership

Every military team has at least one leader (Dyer, 1984; Dyer, Trimble, and Finley, 1980). Teams with echelon organizations (commonly, platoons and higher-echelon teams) generally have designated leader positions at each echelon. Leaders perform much of the planning and decision-making in carrying out collective tasks. These functions require primarily cognitive skills and the performance of specialized leadership tasks (Henriksen, et. al., 1980), which are unlikely to be common to non-leader positions within a team. Loss of the leader-peculiar skills due to turnover has been found to have a significant negative impact on team performance in at least one study of turbulence in tank crews (Eaton and Neff, 1978).

In teams with only one leader (e.g., tank crews) turnover in the leader position results in loss of essentially all the leadership-oriented skills and knowledge available to the team. In teams with multiple echelons of leaders (or with subordinate leaders such as a Platoon Sergeant or executive officer), however, not all of the leadership skills and knowledge are lost when one member leaves the team. This leads to the hypothesis that the impacts of leader turnover on team performance will be smaller if there are multiple or redundant leaders in the team's formal organizational structure.

Parallel reasoning holds for the effects of forgetting. With a larger number of leaders, the specialized leadership skills and knowledge are distributed across a larger number of individuals. Assuming independence of forgetting between individuals, the specific leadership skills needed for a team to perform should show less loss from forgetting, overall, when there are more leaders. Teams with a larger number of leaders will therefore tend to collectively lose a smaller proportion of the needed skills and knowledge through simple forgetting than will a smaller pool of leaders.

These hypotheses are graphically summarized in Figure 8.

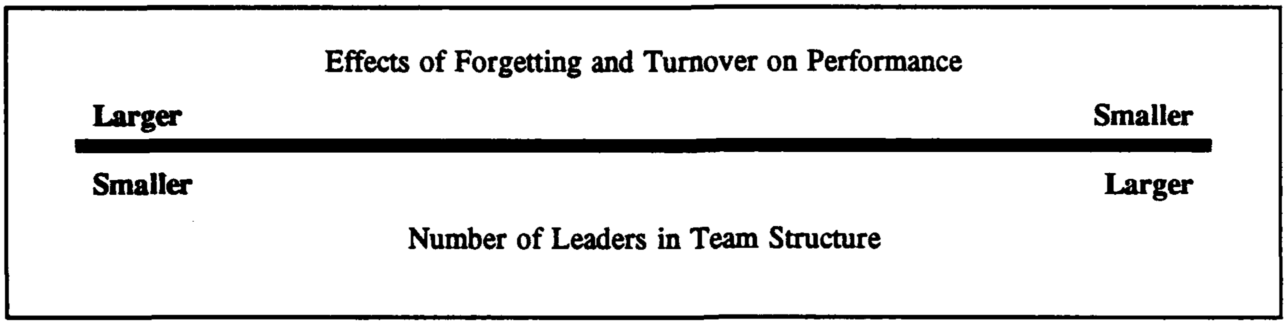

Figure 8. The relationship between number of leaders and retention and stability effects on team performance

Developing a measure to reflect this factor posed some difficulties. Initially, a ratio measure (number of leaders divided by number of non-leaders in the team's formal organizational structure) was considered. A measure reflecting the average direct span of control of each leader in a team type was also considered. This measure was intended to reflect the number of team members that each leader would normally interact with directly (i.e., without the intervention of an intermediate leader). There was very little variability across team types in either measure, however. A more highly variable measure (and, hopefully, a better predictor) is a simple count of the number of leadership positions in a team's formal structure. We will use this measure to reflect this factor.

Summary of Hypotheses About Team Type Attributes

Seven attributes that characterize differences among team types have been included in this taxon. Here, for convenience, we summarize the hypotheses about the influences of each of the attributes on the two primary team performance predictor variables. Table 1 presents the summary.

Taxon 2--Collective Task Sensitivity to Performance Change

This taxon is the second level of the taxonomy. It provides a means for evaluating the collective tasks performed by a team type as to their relative sensitivity to performance change as a result of skill decay and team membership change. The location of a task on the continuum of sensitivity to performance change is established by evaluating six collective task attributes, discussed below. Judgments about the contributions of the attributes on the effects of skill decay and team membership change are then combined to identify where a task falls on the sensitivity continuum relative to other tasks. It should be understood that, while tasks performed by different team types may overlap on this continuum, this taxon does not necessarily provide a means of comparing the sensitivity to performance change of tasks performed by different team types. There is no a priori reason to think that such comparability of tasks among team types may not someday be the case. For now, however, we will not use this taxon to make such comparisons.

As with Taxon 1, the level of measurement on this continuum is, at best, ordinal. It enables a comparison of collective tasks on sensitivity to performance change through predicting greater or lesser response to the effects of the predictors, but does not address the magnitude of the difference.

Table 1

Summary of Hypotheses About Influences of Taxon 1 Attributes

Attribute	Influence of the Attribute on Effects of the Primary Performance Predictors	
	Influence on Skill Decay	Influence on Turnover & Turbulence
Team Size	Larger size increases effects on performance	Larger size decreases effects on performance
Number of Sub-teams in Formal Team Structure	Larger number of sub-teams increases effects on performance	Larger number of sub-teams increases effects on performance
Position Redundancy in Formal Team Structure	Greater redundancy decreases effects on performance	Greater redundancy decreases effects on performance
Number of Equipment Items Used by Team Type	Larger number of equipment items increases effect on performance	Larger number of equipment items increases effect on performance
Number of Collective Tasks Performed by Team Type	Larger number of tasks increases effects on performance	Larger number of tasks increases effects on performance
Number of Individual Tasks Performed by Team Type	Larger number of tasks increases effects on performance	Larger number of tasks increases effects on performance
Number of Leaders in Formal Team Structure	Larger number of leaders decreases effects on performance	Larger number of leaders decreases effects on performance

Considerable attention has been devoted by previous investigators to the characteristics of collective tasks that influence team performance. One variable, originally proposed by Steiner (1972), concerns the way that the product of team members' effort is combined. One dimension of classification Steiner proposed is **unitary** versus **divisible**. Unitary tasks are those that result in a single identifiable product, such as a product coming off an assembly line where multiple workers have executed various processes on the part.

Divisible tasks are those where different team members perform different subtasks that each contributes to a common objective. We believe that most military collective tasks of interest in this context are in fact divisible tasks. An examination of collective task descriptions in AMTPs, and observation of teams performing collective tasks, reveal that effort is in fact divided in this way in most military collective tasks. Frequently, sub-teams are assigned to perform semi-independent functions within the collective task context; there may even be many sub-teams performing different functions or activities at the same time. And, there are often specialized positions (such as the members of a tank crew) that must each perform many inter-related subtasks in order to accomplish any collective task. This appears to conform completely to Steiner's (1972) definition of divisible tasks.

Six attributes related to the characteristics of collective tasks have been identified as important to this effort. These factors are discussed below.

Number of Task Steps

This factor is related directly to forgetting. Research on the retention of individual military tasks (Shields, Goldberg, and Dressel, 1979; Rose, et. al., 1984; Rose, Radtke, Shettel, and Hagman, 1985) indicates that one of the strongest predictors of the forgetting rate of a task is the number of steps required to perform the task. While the predictive value of the number-of-steps variable is greatest for procedural tasks, it has an intuitive appeal, as well. If there are more steps in a task, then there is likely to be more to learn and remember in order to perform the task, other things being equal. And, the more there is to learn and remember, the more is likely to be lost through forgetting over a given period of time.

This is in complete accord with our earlier interpretations of the collective task performance model. Military collective tasks of interest to this effort demonstrate wide variability in the number of "steps" (i.e., subtasks) that are performed across collective tasks. At a minimum, this should be related to the amount team members must recall to perform a collective task, even if only the sequence of steps must be recalled. While many of the factors involved in team performance (e.g., member substitutability, shared knowledge of many of the component individual tasks, etc.) can act to mitigate forgetting effects of this sort, the intuitive appeal and the predictive potency of the number-of-steps variable for individual tasks suggest that this factor be included in our task characterization taxonomy, at least initially. A larger number of steps in a task also implies that more skills and knowledge will be lost when team membership changes, suggesting that this attribute influences both of the primary predictors of performance.

The working hypotheses for this factor are: (a) the larger the number of steps in a collective task, the more the task will be subject to the effects of forgetting over a given period of time; and (b) the larger the number of steps in a collective task, the more the task will be subject to performance deterioration as a result of team membership change (see Figure 9). The total number of subtasks and standards included in AMTP task descriptions will be used as a measure for this variable. While these descriptions are somewhat wanting (from a task analyst's viewpoint) in level of detail, and are often inconsistent in their treatment of what constitutes a subtask, they are the best descriptions available for the collective tasks of interest.

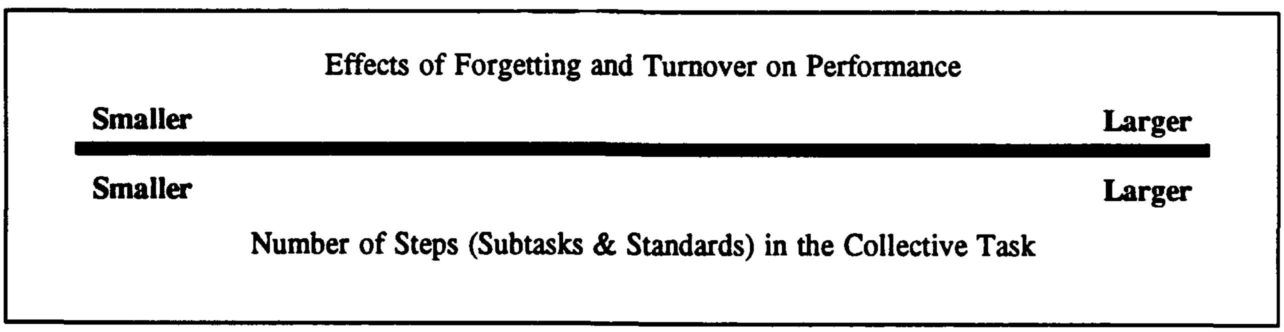

Figure 9. The relationship between number of steps in a collective task and retention and stability effects on team performance

Established versus Emergent

Boguslaw and Porter (1962) appear to have been the first researchers to make this distinction. The distinction between established and emergent situations has structured much thinking and some research in the team performance area since (among others, Alexander and Cooperband, 1975; and Dyer, Trimble, and Finley, 1980 used the emergent-established continuum to describe team tasks and situations). Established tasks are those that are always performed in the same fashion, regardless of the conditions of performance. In contrast, emergent tasks are performed differently depending on the conditions under which the task is performed.

How does this attribute relate to the effects of the primary predictor variables on performance? The answer is closely correlated to the distribution **across** team members of skills and knowledge that support task performance . Established tasks are highly structured in nature, with all team members performing essentially the same actions and adopting the same roles each time the collective task is performed. Therefore, established tasks require that task-specific skills and knowledge, including cues received from other team members in the course of task performance, be learned by most or all team members. Since tasks of this type are performed more or less by rote, the team considered at large is unlikely to lose the skills and knowledge required to perform established tasks through either forgetting or membership change, unless there is an extraordinary degree of specialization and independent action required on the part of many of the members in order to perform the task.

Emergent tasks, on the other hand, may be performed in a different fashion every time the task is done. This suggests that there is a much larger component of planning and selection of alternate courses of action associated with performing such tasks. The skills for planning and generating courses of action are generally possessed by fewer members of a team than those required for established task performance. Most likely, leaders will be the ones that possess these skills, rather than the team's membership in general. Since fewer members possess these skills, the likelihood that the skills needed to perform tasks successfully will be lost by either forgetting or membership change is higher for emergent than for established tasks.

We therefore propose that the more emergent a task is, the more rapidly the skills and knowledge associated with the task will decay without practice, and the greater the effects of membership change will be, other factors being equal. Figure 10 summarizes these hypotheses.

Effects of Forgetting, Turbulence, and Turnover on Performance

Smaller — **Larger**

More Established — **More Emergent**

Emergent-Established Rating of the Collective Task

Figure 10. The relationship between the emergent-established continuum and retention and stability effects on team performance

How, then, are we to determine whether a task is established or emergent? There appear to be no standard criteria in the literature, only

generalized descriptions of the continuum (e.g., Boguslaw and Porter, 1962). For purposes of this effort, it was decided that Subject Matter Expert (SME) rating of a task, according to a rating scale, would be used to assess this characteristics of tasks. The rating scale that was developed is presented in Figure 11.

RATING	DESCRIPTION
5	**HIGHLY EMERGENT.** The procedure or sequence of steps for performing this task cannot be specified in advance at all, without knowing the conditions under which the task takes place. The way the task is performed is very sensitive to changes in the conditions under which it is performed. The way the task is performed can be changed at any time during the task in response to changes in conditions.
4	**PRIMARILY EMERGENT.** A procedure or sequence of steps for performing some parts of the task can be specified in advance, without knowing the conditions under which the task is performed. Most parts of the task are sensitive to the conditions under which it is performed. The way such parts of the task are performed can be changed in response to changes in conditions.
3	**ABOUT EQUALLY ESTABLISHED AND EMERGENT.** A procedure or sequence of steps can be specified in advance for about half of the task, without knowing the conditions under which the task is performed. About half of the task is sensitive to the conditions under which it is performed. The way such parts of the task are performed can be changed in response to changes in conditions.
2	**PRIMARILY ESTABLISHED.** A procedure or sequence of steps can be specified in advance for most parts of the task, without knowing the conditions under which the task is performed. Few parts of the task are sensitive to the conditions under which it is performed. Only minor parts of the task are performed differently when conditions change.
1	**HIGHLY ESTABLISHED.** A procedure or sequence of steps exists for every part of the task. This procedure is always followed in exactly the same way to accomplish the task. There is no change in the way the task is performed due to changing conditions.

Figure 11. A rating scale for the established-emergent collective task continuum

Sub-teams in Task Performance

Dyer (1984) points out a critical characteristic of the performance of collective tasks by military teams—the team may use an organization different than the one suggested by the team's **formal** structure in carrying out a task. Dyer referred to this as the "active" team structure. An examination of

collective tasks descriptions in AMTPs confirms this observation. Variable numbers of sub-teams perform different activities in different stages of most collective tasks. However, the sub-team organization can differ significantly from task to task. At times, the entire formal team will be performing essentially the same activity; at other times there may be many active sub-teams performing different activities. This is often referred to as **task-organization** in military tasks: specific sub-teams within the formal team organization (e.g., squads within a platoon) are grouped together to accomplish different functions within the task at large.

This phenomenon has implications for the impact of the predictor variables on team performance. The reasoning for this hypothesized impact parallels the argument given for the number of sub-teams in the formal organizational structure of the team, above. The more sub-teams there can be for a given task, the more that the team as a whole must learn and remember about the relationships between the sub-teams, expected patterns and modes of communication between the sub-teams, etc. Therefore, a larger number of sub-teams implies a larger learning and memory requirement for the team as a whole. And, according to our overall hypothesis on retention, the more there is to learn and remember, the greater the impact of forgetting on performance over a given period of time. As well, a larger number of sub-teams implies greater specialization is needed during a particular task. Therefore, the impact of membership change may be greater if a task involves more sub-teams. Our hypotheses for this attribute are that the larger the number of sub-teams into which a team is organized to perform a given collective task: (a) the more performance on that task will be affected by skill decay over a given period of time; and (b) the more performance will tend to be affected by a given level of membership change. These hypotheses are graphically represented in Figure 12.

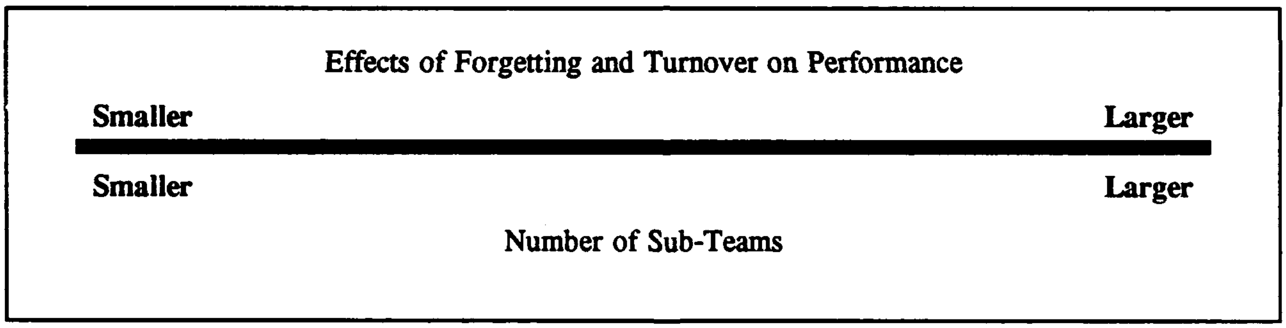

Figure 12. The relationship between number of sub-teams organized in performing a collective task and retention and stability effects on team performance

The need for a measure for this factor brings to light a phenomenon that is interesting in its own right—the variability in the number of task-organized sub-teams **within** a collective task. In examining the collective task descriptions in AMTPs, it is apparent that the same sub-teams do not exist at all stages of performing a collective task. There is frequently a dynamic change in the organization of a team from one subtask to another within a collective task. In some subtasks, the entire team engages in the same activity, while in other subtasks, different 'constellations' of sub-teams perform different activities. Task organization can and does change to meet the requirements of subtasks for parallel, semi-independent activities.

In order to reflect this variability from subtask to subtask within a collective task, we average the number of sub-teams performing in each subtask over all the subtasks in the collective task at large. This helps to compensate for the variability in the number of subtasks from one collective

task to another, so that we can make meaningful comparisons of this variable across tasks. A timeline analysis of the task of interest, based on the task descriptions in the AMTPs, is used to compute the measure. Figure 13 presents the procedures and a sample timeline for computing the measure.

Instructions. Using the ARTEP MTP Training and Evaluation Outline (T&EO) as an initial source, develop a sequential timeline of the subtasks performed in conducting the collective task of interest. See the diagram below for an example. This timeline need not be keyed to time-based milestones, but it must reflect the sequence of subtasks that are performed in the collective task. Use this timeline as the horizontal axis of a matrix (in the diagram, there are four subtasks). Use the T&EO task description and supplemental tactical and doctrinal publications necessary for the remainder of this process. Next, identify each sub-team into which the unit is divided during performance of the collective task of interest. List the sub-teams as separate entries on the vertical axis of the matrix (in the diagram, there are three sub-teams).

For each sub-team, list the general activity that the sub-team performs during each subtask, in the body of the matrix. Then, examine the activities performed by the sub-teams in each subtask. If necessary, add additional sub-teams or subtasks to the matrix until the matrix is a complete description of the different sub-team activities and subtasks. Next, count the number of different activities that are performed by sub-teams in the subtask (in the diagram, there are two, three, three, and two different sub-team activities involved in the four subtasks). Then, total the number of different sub-team activities across the subtasks (in the diagram, the total is 10). Divide the total by the number of subtasks, and round to one decimal place (the result in the diagram is 2.5).

Team Type: Light Infantry Squad **Task: Assault**

Sub-teams	**Subtasks 1**	**2**	**3**	**4**
1. **Platoon Leader**	Organize, C3	C3, Direct	C3, Direct	C3, Direct
2. **Assault Element**	Organize, Prepare	Move to Position	Fire and Movement	Consolidate & Reorganize
3. **Support Element**	Organize, Prepare	Suppressive Fire	Lift/Shift Fire	Consolidate & Reorganize
Total No. Sub-teams Performing Different Activities	2	3	3	2

$$\frac{\text{Sum} = 2 + 3 + 3 + 2 = 10}{\text{Total No. Subtasks} = 4} = \textbf{Measure (2.5)}$$

Figure 13. Procedures for computing the number of sub-teams per subtask, and an example of a timeline and computations

Individual Task Performance

Just as there is variation between team types in the number of individual tasks performed, there is variability between specific collective tasks for a given team type. The individual tasks required to support task performance are not the same for all collective tasks. Using the same logic as used for this attribute with respect to team types, we hypothesize that the number of individual tasks that support a collective task is related to the impact of forgetting on collective task performance. The larger the number of individual tasks required to support a collective task, the more performance will deteriorate with increases in the retention interval. Likewise, the larger the number of individual tasks performed in the course of a collective task, the greater the impact of membership change on performance of that task will be. These hypotheses are summarized graphically in Figure 14.

The measure for this attribute is the same as for the individual-tasks attribute for team types, except that the individual tasks are counted per collective task, rather than for the team type at large. Again, common tasks (if listed in an AMTP) should be excluded from the count.

Effects of Forgetting and Turnover on Performance

Smaller — **Larger**

Smaller — **Larger**

Number of Individual Tasks Performed During a Collective Task

Figure 14. The relationship between the number of individual tasks performed during a collective task and retention and stability effects on team performance

Coaction Versus Interaction in Task Performance

Coaction and interaction are two extremes of a dimension characterizing the fashion in which team members interact while performing a collective task (Bird, 1978; Landers and Lueschen, 1974; Kahan, Webb, Shavelson, and Stolzenburg, 1985). A coactive task is one where all unit members or sub-teams perform similar or identical activities simultaneously, generally under central direction or leadership. Communication tends to be unidirectional, from the team leader to team members. Team members tend to adapt their activities in a similar way as a result of directions. An example of a coactive task is an armor platoon preparing for an anticipated nuclear attack by opposing forces. Certain equipment on each tank is turned off, secured, or otherwise protected. Each member of the platoon dons personal protective equipment. Each crew (sub-team) and each individual performs essentially the same actions in response to an order to make preparation for such an attack.

An interactive task is one where individual team members or sub-teams perform different activities, often asynchronously. Communication in interactive tasks tends to be multidirectional, and sub-teams or individual team members may respond to communications or directions in different fashions. An armor platoon preparing for combat exemplifies a relatively highly interactive task. Each individual crew member and leader has the responsibility for checking particular items of equipment and supply, performing inspections, and communicating status information to other team

members. Shortfalls in equipment condition or other status items are detected, and instructions for remedying the shortfalls are issued. The preparation process continues (subject to time limits) until the unit is as ready as possible, given the constraints under which it performs the task.

What impact does this task factor have on the predictor variables? Tasks which are more coactive than interactive may be less sensitive to performance decay without training, since most or all team members do similar things in performing the task. This means that there may be many opportunities for team members who have forgotten some knowledge or skill to model their behavior in the task after that of others, or to pick up critical task performance cues from other team members. This reduces the impacts of forgetting on performance. Parallel reasoning holds for the effects of membership change. There will be more individuals who can be used as mentors or behavior models in a coactive task than in an interactive one. This means that membership change will have less impact with tasks that are more coactive than interactive. We therefore hypothesize that collective tasks that are characterized as more interactive than coactive will be more sensitive to performance decay without practice and to the effects of membership change than will tasks that are characterized as more coactive than interactive (see Figure 15).

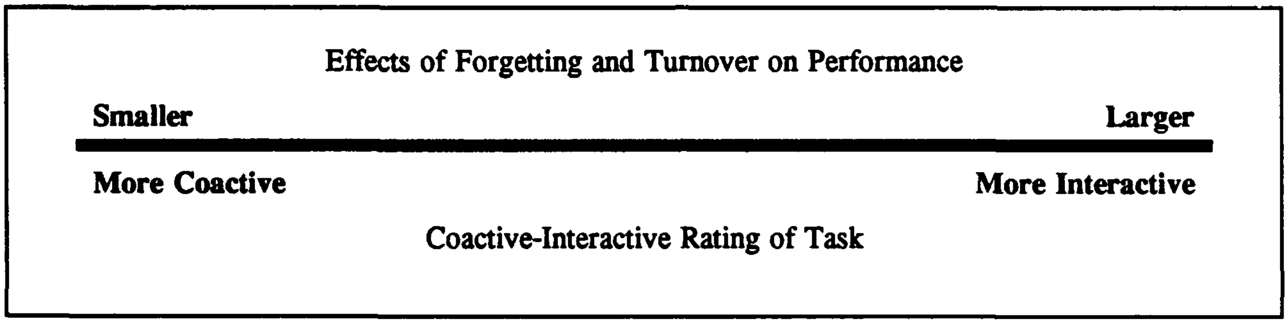

Figure 15. The relationship between the coactive-interactive continuum and retention and stability effects on team performance

There is no standardized measure for this factor in the literature. To provide a measure, another rating scale was developed to characterize the coactive-interactive continuum. This scale is presented in Figure 16. In accordance with the prediction of our hypothesis, the scale reflects a larger value as tasks are rated toward the interactive end of the continuum.

Potential for Compensation or Correction in Task Performance

Several authors have noted as a key characteristic of team behavior and performance the ability of one member of a team to compensate for less than adequate performance of other members (George, 1979; Nieva, Fleishman, and Reick, 1978; Dyer, 1980; Shaw, 1976). This can include providing guidance or corrections to the behavior of another team member, or what has been termed 'load balancing:' performing part or all of a task in another member's stead (Lanzetta and Roby, 1956). The phenomena of compensation and correction within collective task performance may act to offset less than adequate performance on the part of team members. This would act in opposition to decrements in performance associated with either skill and knowledge decay or changes in team membership.

Our hypotheses about the effects of this factor are: (1) the greater the potential for correction or compensation to take place in the performance

RATING	DESCRIPTION
5	**HIGHLY INTERACTIVE.** Individual unit members and sub-teams consistently perform qualitatively different activities and respond in different ways to orders or directions throughout the performance of the task. At no time during task performance are there activities where all team members and sub-teams perform the same activities at the same time.
4	**PRIMARILY INTERACTIVE.** Individual unit members and sub-teams perform qualitatively different activities and respond in different ways to orders and directions in most aspects of performing the task. In some minor parts of the task, all team members or sub-teams perform the same activities at the same time.
3	**ABOUT EQUALLY INTERACTIVE AND COACTIVE.** Individual unit members and sub-teams perform qualitatively different activities and respond in different ways to orders and directions in about half of the performance of the task. In about half of the task, all team members or sub-teams perform the same activities at the same time.
2	**PRIMARILY COACTIVE.** Individual unit members and sub-teams perform the same activities at the same time and respond in the same ways to order and directions in most aspects of performing the task. In some minor parts of the tasks, individuals or sub-teams perform activities that are qualitatively different from those of the remainder of the team.
1	**HIGHLY COACTIVE.** Individual unit members and sub-teams perform the same activities at the same time and respond to orders or directions in the same ways throughout the performance of the task. At no time during task performance do individuals or sub-teams perform activities that are qualitatively different from those of other team members.

Figure 16. A rating scale for the coactive-interactive continuum

of a collective task, the less task performance will be affected by decay of skills and knowledge without practice; and (2) the greater the potential for correction or compensation to take place in the performance of a collective task, the less task performance will be affected by turnover or turbulence (See Figure 17).

The actual amount of compensation and correction in a performance of a collective task is probably variable. At some times, there will be a greater need for these functions, particularly when there has been high turnover (skills at working with the team are lower than otherwise) or when there has been an extended period without collective task practice (all skills and knowledge have decayed somewhat). Since we are unable to deal directly with this possible variability at this time, a means of characterizing the task in the abstract on this factor is needed. Accordingly, a rating scale was

developed to capture the potential for correction or compensation to redress less than adequate performance in collective task performance. Since attribute may vary within a collective task, the rating scale is to be used by a MTP subtask, and the ratings averaged over all subtasks within a collective task. This rating scale is presented in Figure 18. The anchors of the rating scale are ordered to reflect the relative impact of this attribute. A low rating on this factor indicates that performance will be affected less than if a high rating is assigned to a collective task.

Effects of Forgetting, Turbulence, and Turnover on Performance

Larger — **Smaller**

Less Potential — **More Potential**

Rated Potential for Correction or Compensation

Figure 17. The relationship between potential for correction or compensation and retention and stability effects on team performance

Summary of Hypotheses About Team Type Attributes

Six attributes that characterize differences among collective tasks have been included in this taxon. Here, for convenience, we summarize the hypotheses about the influences of each of the attributes on the two primary team performance predictor variables. Table 2 presents the summary.

Taxon 3--Specific Team Sensitivity to Performance Change

This taxon is the final level of the taxonomy. It identifies attributes that can be used to evaluate the relative sensitivity of specific teams (i.e., first squad, first platoon, A company) as to their relative sensitivity to performance change as a result of skill decay and team membership change. The location of a specific team on the continuum of sensitivity to performance change can be established by evaluating three team attributes. These attributes are characteristics of the members of the team which may influence the ability of the team at large to express the skills and knowledge needed to perform collective tasks. The literature on both retention and team performance supports the general notion that the characteristics of team members should make a difference to collective task performance. Specific citations are presented to support our arguments in the paragraphs that follow.

Aptitude

Experimental studies of retention of skills and knowledge associated with military type tasks (Hall, Ford, Whytten, and Plant, 1983; Vineberg, 1975; Black, 1980) indicate that higher-aptitude (as indicated by Mental Category) personnel typically learn to criterion level more rapidly and retain more learned material over a given retention interval. These results are specific to individual tasks. An alternative explanation is that higher

RATING	DESCRIPTION
1	**HIGH POTENTIAL FOR CORRECTION OR COMPENSATION.** There are many opportunities for correcting or compensating for inadequate performance of sub-teams in this subtask. Most or all leaders and sub-teams are aware of the performance of most other sub-teams at any time in this subtask. Other sub-teams can easily provide resources, or leaders can easily direct changes in the activities of the team, to ensure that all sub-teams' activities are successfully accomplished. The team as a whole is at a relatively low level of workload in this subtask.
2	**MODERATE POTENTIAL FOR CORRECTION OR COMPENSATION.** There are some opportunities for correcting or compensating for inadequate performance of sub-teams in this subtask. At least one other sub-team or leader is aware of the performance of every sub-team at any time in this subtask. Other sub-teams can provide resources at some cost to successfully accomplishing their own activities, or leaders can sometimes direct changes in the activities of the team, to attempt to accomplish all sub-teams' activities successfully. The team as a whole is at a moderate level of workload in this subtask.
3	**LOW POTENTIAL FOR CORRECTION OR COMPENSATION.** There are few or no opportunities for correcting or compensating for inadequate performance of sub-teams in this subtask. There are times when no leader or other sub-team is aware of the performance of a sub-team in this subtask. Other sub-teams cannot provide resources to an inadequately performing sub-team without causing their own performance to be inadequate. Leaders cannot easily direct changes in the team's activities, to attempt to accomplish all sub-teams' activities successfully. The team as a whole is at a high level of workload in this subtask.

Figure 18. A rating scale for the potential for correction or compensation in a collective task

aptitude personnel learn more than lower aptitude personnel during initial skill and knowledge acquisition, but that the rate of decay for all levels of aptitude is the same. Whichever explanation is chosen, the result is the same: higher aptitude personnel retain more of what they have learned, and perform more proficiently, over a given retention interval, than do lower aptitude personnel. There seems to be no reason that this finding should not generalize to skills and knowledge associated with performing as team members.

The obvious hypothesis with respect to this variable is that higher-aptitude teams should forget less per unit time without practice (see Figure 19). This in turn means that the performance of higher-aptitude teams will be affected less by forgetting over an equivalent retention interval than the performance of lower-aptitude teams.

Williams and Sternberg (no date) suggest that a multidimensional metric is needed to characterize the aptitude of teams. They propose that both the average aptitude of team members, as well as the level of aptitude of the most proficient member, be represented in measures of team aptitude. Accordingly, a metric for this variable can be defined.

Table 2

Summary of Hypotheses About Influences of Taxon 2 Attributes

Attribute	Influence of the Attribute on Effects of the Primary Performance Predictors	
	Influence on Skill Decay	**Influence on Turnover & Turbulence**
Number of Task Steps (Subtask and Standards)	More steps increases effects on performance	More steps increases effects on performance
Established versus Emergent Rating of Task	More emergent increases effects on performance	More emergent increases effects on performance
Average number of sub-teams per subtask	Larger number increases effects on performance	Larger number increases effects on performance
Number of Individual Tasks Performed in Collective Task	Larger number of tasks increases effects on performance	Larger number of tasks increases effects on performance
Coactive versus interactive rating of task	More interactive rating increases effects on performance	More interactive rating increases effects on performance
Rating of potential for compensation or correction in task performance	Higher rating increases effects on performance	Higher rating increases effects on performance

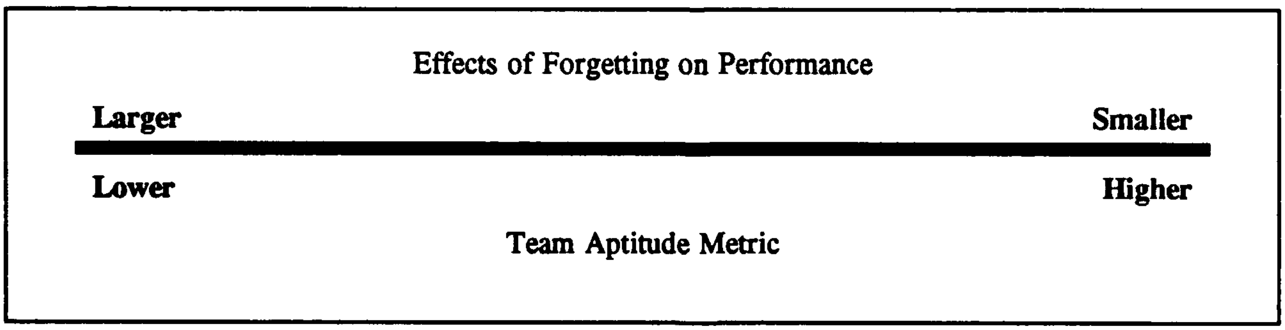

Figure 19. The relationship between team aptitude and retention effects on team performance

A common measure of the aptitude of individual military members is the member's score on the Armed Forces Qualification Test (AFQT). It seems intuitively reasonable to use this measure to develop a team aptitude metric, as well. Accordingly, we define the metric for this attribute as the mean of AFQT scores of all personnel assigned as members of a particular team, plus the AFQT score of the highest-aptitude team member. This metric has the additional desirable quality of being insensitive to the number of members

assigned to the team. This may be useful in predicting the relative performance of teams of different sizes, or teams of the same type with different levels of personnel fill in their formal structures.

Training and Experience

In terms of skill and knowledge development, training and experience can be thought of as providing initial and additional opportunities to learn, or to develop effective and elaborated knowledge representation and recall structure (KRRSs). The combination of formal and informal training, and experience on the job, may lead to **overlearning**, that is, additional learning that takes place after the initial task criterion has been reached (McGeoch and Irion, 1952). The degree of overlearning has been cited as an extremely important determinant of long-term retention (Loftus, 1985). Overlearning has also been associated with the development of KRRSs that are more resistant to forgetting (Kunen, Green, and Waterman, 1979).

When considering team performance, we distinguish between two elements of team members' training and experience: (1) overall training and experience as a member of the military; and (2) training and experience as a member of the team.

To deal with the second element first, this may be an elusive quality to capture, in a practical sense. While personnel records may identify the period of time an individual has been associated with a particular team, there may be occasions during that period when an individual has not actually been a team member. For instance, an individual may fill a TOE position in a team's organization on paper, but actually work at a Temporary Duty (TDY) or Special Duty (SD) assignment in a different organization or even a different location. Such administrative absences from team membership are not typically measurable. The implication is that there is unlikely to be any direct measure of members' relevant training and experience **as team members**.

An **indirect** measure of the overall training and experience of **a team working together**, however, has already been mentioned—turnover. The higher the rate of turnover, the less likely it is that all members of a team will have developed and retained the critical teamwork-oriented knowledge and skills necessary to perform collective tasks at a high level of proficiency, other factors being equal. Therefore, we will use the rate of turnover in team membership as a measure, expressed as percent per month, for this experience working as a team. Higher levels of turnover are hypothesized to be related to less overall experience working as a team, and predict less proficient collective task performance. This is shown graphically in Figure 20.

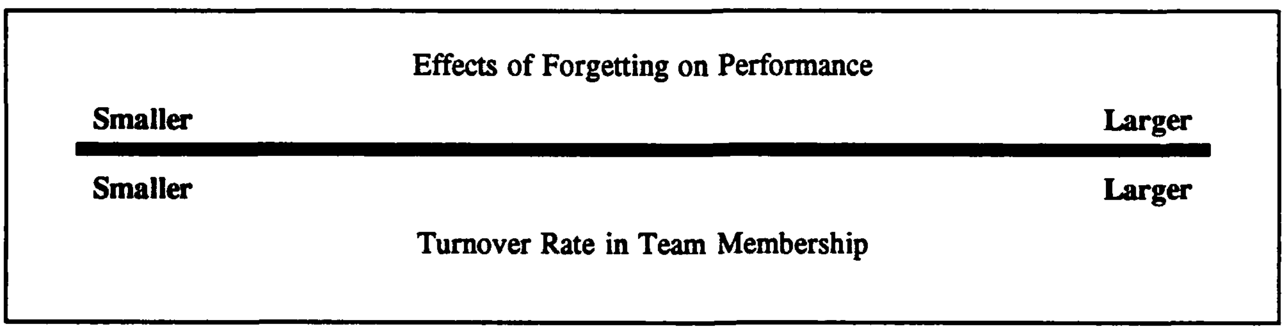

Figure 20. The relationship between turnover and retention effects on team performance

The second element of training and experience relates to overall history as a military member. In general, training and experience are correlated with a number of characteristics of a military member: total length of service, paygrade, and Skill Level within MOS. Of these, the paygrade of team members probably reflects qualities of most interest from our point of view. Paygrade is highly correlated with assigned MOS Skill Level (for enlisted personnel), which indicates proficiency in certain tasks specific to an MOS, or completing training designed to produce proficiency in those tasks. Therefore, paygrade can be thought of as directly related to particular competencies in job performance.

A composite metric will be used for this variable, for two reasons. First, it is desirable to reflect the multidimensional nature of team member characteristics. As with aptitude, both the average and the highest among the team should be represented in a metric (Williams and Sternberg, no date). Second, a composite metric allows for including both officer and enlisted personnel. This cannot be done with some other possible measures, such as Skill Level (officers do not have assigned Skill Levels). The metric is computed by averaging four values:

1. The average paygrade of all enlisted personnel assigned to the team;

2. The paygrade of the highest-ranking enlisted member of the team;

3. The average paygrade of all officer personnel assigned to the team; and

4. The paygrade of the highest-ranking officer assigned to the team.

An appropriate denominator should be used in computing the average. That is, the denominator should reflect only the number of figures used to compute the numerator. For example, if no officers are included in the formal structure of the team type of interest (as with an Infantry squad), then only the two values for enlisted personnel should be added to make the numerator of the equation, and the denominator should be two. Or, if officer positions are authorized but not filled (e.g., an Infantry platoon with no Platoon Leader), only values for enlisted personnel should be used to compute the numerator. In this case, the denominator would also be two.

This metric is insensitive to the number of personnel actually assigned to a team. This enables comparing experience among teams some of which may be understrength, or experiencing shortfalls of grades of assigned personnel to the authorized grades for their positions. However, it should be used only to make comparisons among teams of a given type. Teams of different types should not be compared using this metric, because the attributes associated with the design of different team types vary.

The working hypothesis is that the higher the paygrade metric for a team, the less the effects of forgetting on performance, other factors being equal (Figure 21).

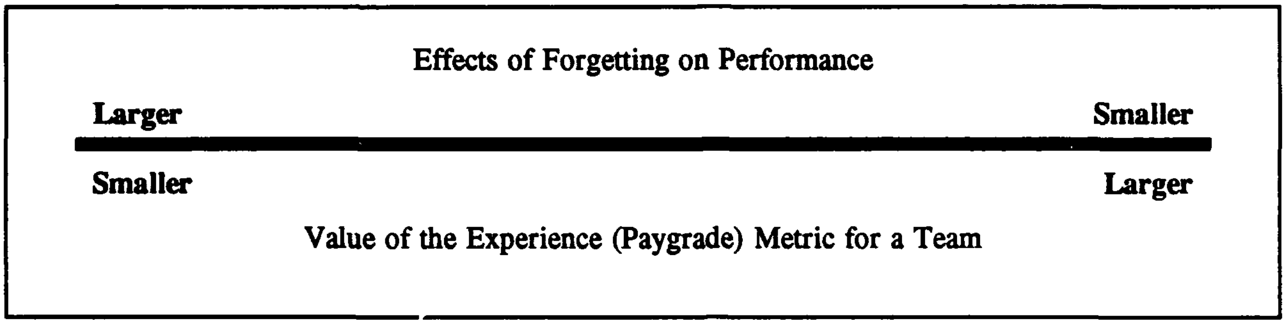

Figure 21. The relationship between the experience (paygrade) metric and retention effects on team performance

Summary of Hypotheses About Specific-Team Attributes

Here, we summarize the hypotheses about the influences of each of the attributes. Table 3 presents the summary.

Table 3

Summary of Hypotheses About Influences of Taxon 3 Attributes

Attribute	Influence of the Attribute on the Effects of Forgetting
Aptitude Metric	Larger metric reduces effects on performance
Turnover Rate per Month (Experience as a Team)	Larger rate increases effects on performance
Overall Military Experience of Team Members (Paygrade Metric)	Larger metric reduces effects on performance

TAXONOMY APPLICATION AND PARTIAL VALIDATION

In order to evaluate the fa·ɜ validity of the first two taxa described in the previous section, as well as to use the results in the task sampling process, these taxa were applied to teams types and collective tasks of primary interest in the research at large. In addition, data to conduct a partial validation of predictions made by using Taxon 2 became available; a preliminary validation was conducted. This section of the report describes the application of the two taxa and the partial validation of Taxon 2 predictions.

Application of Taxon 1 to Characterize Team Types

In the absence of justification for a more elaborate scheme for applying the attributes in this taxon, we chose to classify each team type as "high" or "low" impact on performance with respect to each attribute, and combine the results. The classification was done separately for each of the seven attributes. The number of "high" ratings for each team type was then summed for each of the two predictor variables. This gives a relative impact score for forgetting, and, separately, for membership change, for a team type. These are in turn summed, to yield an overall measure of the location of the team type on the continuum of sensitivity to performance change. This was the desired outcome of applying Taxon 1 attributes—a means to compare team types as to performance change sensitivity.

The total sensitivity score for a team type can range from zero to 12. A score of zero indicates a relatively small impact on performance change of either forgetting or membership change for a team type. On the other end of the continuum, a score of 12 would be interpreted as indicating a relatively high level of sensitivity to performance change as a result of both forgetting and membership change.

Eight representative combat arms team types were evaluated according to the scheme above, to develop sensitivity scores. Data to evaluate each attribute for the team types were derived from the AMTPs for appropriate team types, and from tactical and doctrinal publications pertaining to the team types. The raw data for the eight team types are shown in Table 4. Examining the data in Table 4, two features are apparent. First, there is considerable variability on each of the seven attributes. This provides a certain amount of face validation the attributes that were selected. At least the attributes capture some aspects of the variability between team types.

Second, the distributions of the team types' scores on each attribute suggest a straightforward means of dividing the derived scores on each attribute into "high" and "low" classifications. For example, using the 'number of members' factor, four of the team types have fewer than ten members, while the remaining four have more than ten members. It was decided that these apparent 'breaks' in the distributions of scores on the attributes would be used to make the "high" versus "low" impact distinctions. This decision is admittedly arbitrary. However, some scheme was needed for making the "High" versus "Low" distinction. This scheme is at least rational, even though it may need revision at a later time. Table 5 presents the 'cut points' for the attributes distributions selected as a result of this process.

Applying the 'cut points' in Table 5 yields the "High" and "Low" classifications on the seven attributes for each team type. These are

Table 4

Team Type Attributes Raw Data for Eight Representative Team Types

Team Type	Attributes						
	Number of Members	Position Redun-dancy	Number of Subteams	No. Equip. Items per Member	Number of Individual Tasks	Number of Collective Tasks	Number of Leaders
Mechanized Infantry Platoon	32	20	7	3.74	182	58	8
Light Infantry Platoon	34	24	9	1.23	98	62	10
Armor Platoon	16	10	6	3.81	146	65	4
MLRS Firing Platoon	16	7	6	1.94	72	17	5
Mechanized Infantry Squad	9	1	2	3.33	121	28	2
Light Infantry Squad	9	4	3	1.22	38	45	3
Tank Crew	4	0	0	3.75	146	65	1
MLRS Firing Section	3	0	0	1.66	67	14	1

Table 5

'Cutpoints' for Team Type Attributes

Attribute	Values for 'Low' Range	Values for 'High' Range
Number of Members	10 or less	More than 10
Position Redundancy Metric	10 or more*	Less than 10
Number of Sub-teams	5 or less	More than 5
Average Number of Equipment Items per Team Member	2.0 or less	More than 2.0
Number of Individual Tasks	100 or less	More than 100
Number of Collective Tasks	50 or less	More than 50
Number of Leaders	5 or less	More than 5

* The apparently counter-intuitive judgments on this attribute are due to the fact that *greater* position redundancy predicts *reduced* impact of both predictors on performance.

presented in Table 6. Note that it was not felt necessary to have an equal number of team types on either side of the distribution 'cut points' for the attributes. Since this is only a small sample of team types, it is not yet known whether these 'cut points' are generalizable to cover all team types.

Table 6

Team Type Attributes Impacts for Eight Representative Team Types

Team Type	Attributes						
	Number of Members	Position Redundancy	Number of Subteams	No. Equip. Items per Member	Number of Individual Tasks	Number of Collective Tasks	Number of Leaders
Mechanized Infantry Platoon	High	Low	High	High	High	High	High
Light Infantry Platoon	High	Low	High	Low	Low	High	High
Armor Platoon	High	Low	High	High	High	High	Low
MLRS Firing Platoon	High	High	High	Low	Low	Low	Low
Mechanized Infantry Squad	Low	High	Low	High	High	Low	Low
Light Infantry Squad	Low	High	Low	Low	Low	Low	Low
Tank Crew	Low	High	Low	High	High	High	Low
MLRS Firing Section	Low	High	Low	Low	Low	Low	Low

Combining the "High" and "Low" judgments from Table 6 yields scores for overall predicted sensitivity of team performance to forgetting and membership change. These scores, as well as the combined predictor scores, are summarized in Table 7.

From Table 7, it is evident that there is substantial variability among the team types on the predicted impacts of both predictor variables upon performance, as well as in the total predicted sensitivity to performance deterioration. Armor and Mechanized Infantry Platoons are predicted to be the most affected by the effects of forgetting; both are also predicted by these scores to be sensitive to the effects of membership change, as well. At the opposite end of the continuum, the performance of both Light Infantry Squads and MLRS Firing Sections is predicted to be affected less by either forgetting or membership change. The remaining team types fall at intermediate points on the distribution. It should be kept in mind that the projected effects of the predictor variables are **relative** among team types, and have no inherent meaning with respect to absolute changes in performance.

Correlations Among the Factors

In order to determine whether there are significant redundancies among the factors used to predict team types' relative sensitivity to performance change, correlations between the measures were computed. These correlations are based on the raw data presented in Table 4. While the number of observations on which the correlations are based is relatively small, the coefficients give some idea of the amount of redundancy between the seven variables. Table 8 presents the correlations.

The pattern of correlations in Table 8 indicates that there are some redundancies among the seven factors. Of particular interest are the indications of strong relationships between the four factors related directly to the organizational structure of the team--number of members, position redundancy, number of sub-teams, and number of leaders. This indicates that there is at least some general structural similarity among the eight team

Table 7

Predicted Sensitivity to Performance Change Due to Forgetting and Membership Change for Eight Representative Team Types

Team Type	Score for Impact of Forgetting	Score for Impact of Membership Change	Total Impact Score
Mechanized Infantry Platoon	6	6	12
Light Infantry Platoon	4	4	8
Armor Platoon	5	5	10
MLRS Firing Platoon	3	2	5
Mechanized Infantry Squad	3	3	6
Light Infantry Squad	1	1	2
Tank Crew	4	4	8
MLRS Firing Section	1	1	2

types. Practically speaking, the size of the six statistically significant correlations among these variables would suggest that one of the four variables be selected and used as representative of the set. However, we do not know at this point whether this would affect practical application of a taxonomy for predicting sensitivity of performance to deterioration. There may be independent effects related to each factor, even though the factors are highly correlated in this sample of team types. When more data become available, a decision on whether to use all four of the correlated variables or some subset of them must be made.

The only other statistically significant correlation in Table 8 is between the average number of equipment items per team member and the number of individual tasks. This is an intuitively reasonable relationship. As the number of equipment items increases, the number of tasks required to operate and maintain the equipment items should increase also.

None of the other correlations in Table 8 suggest that factors are redundant. While there are a number of positive correlations between other variables, these account for only small proportions of the variance between pairs of variables.

Application of Taxon 2 to Characterize Collective Tasks

This taxon represents a continuum of predicted sensitivity of performance to degradation due to the effects of the two primary predictors. Taxon 2 uses the six collective-task attributes identified, in exactly the same way that Taxon 1 uses the team-type factors. Evaluation of the attributes for this taxon results in a score for a collective task of from zero to 12. The interpretation of these scores is exactly analogous to the scores for team types. Higher scores indicate greater sensitivity of the task in question to the effects of forgetting and personnel change. Also as for

Table 8

Correlations[a] Among the Seven Team Type Attributes for the Sample of Eight Representative Team Types

	Attributes	2	3	4	5	6	7
1.	Number of Members	**.987**	**.892**	-.036	.367	.439	**.981**
2.	Position Redundancy	---	**.861**	-.084	.335	.503	**.982**
3.	Number of Sub-teams		---	-.020	.248	.333	**.889**
4.	Average Number of Equipment Items per Member			---	**.878**	.590	-.185
5.	Number of Individual Tasks				---	.594	.225
6.	Number of Collective Tasks					---	.390
7.	Number of Leaders						---

[a] The critical value for *r* for seven degrees of freedom at the .01 level of confidence is .798 (boldface in table).

team-type scores, the scale is relative from task to task. However, the scores should not be used to draw conclusions about the relative sensitivity to performance deterioration of tasks performed by different team types.

The six attributes were applied to collective tasks performed by three team types: Light Infantry Platoon, Mechanized Infantry Platoon, and Armor Platoon. Task descriptions in applicable AMTPs, supplemented with a set of task analysis aids, were used to apply the factors. The task analysis aids[1] consisted of extracts from various Army tactical and doctrinal publications illustrating typical ways in which the collective tasks could be performed. Behavioral scientists with military backgrounds performed the application of the factors. The rating scales described in the previous section were used to develop ratings for the established-emergent, coactive-interactive, and potential-for-correction-or-compensation-in-task-performance continua. For brevity, only the collective task scoring for the Light Infantry Platoon is presented, although we will later refer to data on tasks performed by the other team types, as well. A number of collective tasks that are performed by these team types were not evaluated. These were tasks where the AMTP task descriptions were very general, or where the language used in describing a task was ambiguous to the point where judgments about one or more factors could not be made.

Raw score data for the Light Infantry Platoon collective tasks are shown in Table 9. As expected, the tasks showed substantial variability on each of the attributes. A close examination of the data for each attribute was made

[1] Special thanks are directed to Dr. James A. Thomas, who developed the task analysis aids for use in this activity.

Table 9

Raw Data on Collective Task Attributes for Light Infantry Platoon Tasks

Task Title	Attributes					
	Number of Subtasks	Established *versus* Emergent	Number of Subteams	Number of Individual Tasks	Coactive *versus* Interactive	Potential for Correction/ Compensat.
Prepare for Chemical Attack	4	2	1.8	7	2	1
Defend Against Air Attack	8	1	1.5	1	1	2
Cross Nuclear Contaminated Area	8	2	2.0	7	2	1
Maintain Operations Security	5	2	1.4	20	2	1
Prepare for Nuclear Attack	2	2	2.0	7	2	1
Cross Chemically Contaminated Area	5	3	2.0	10	2	1
Overwatch/Support by Fire	7	2	1.4	37	2	1
Reconnoiter Route	4	3	1.0	17	2	1
Perform Helicopter Movement	8	2	3.0	11	2	2
Employ Fire Support	8	2	1.1	10	4	2
Perform Passage of Lines	5	2	2.4	13	2	2
Infiltrate/Exfiltrate	3	4	2.0	12	2	2
Perform Area Ambush	3	4	1.3	29	2	2
Reconnoiter Zone	10	4	0.0	17	2	2
Occupy Objective Rally Point	3	2	2.0	3	3	2
Occupy Observation Post/ Surveillance	5	2	2.0	7	3	2
Perform Boat Movement	9	2	3.0	4	2	2
Conduct Stay-Behind Operation	9	5	1.0	55	2	2
Cross Water Obstacle	14	3	2.1	8	3	1
Clear Buildings	6	3	1.2	15	3	2
Construct Obstacles	6	4	2.0	13	3	2
Breach an Obstacle	12	3	3.4	13	4	2
Occupy Assembly Area	8	2	1.4	51	3	2
Assault	4	3	2.5	26	4	1
Perform Aerial Resupply	7	3	2.4	4	3	1
Perform Link-up	4	3	2.3	9	3	2
Reconnoiter Area	5	3	2.4	17	4	1
Defend a Built-up Area	14	3	1.4	61	3	2
Clear Woodline	6	3	2.2	21	2	2
Perform Anti-Armor Ambush	5	4	2.6	30	4	2
Perform Hasty Ambush	12	4	1.1	18	3	2
Clear Trenchline	11	3	1.5	25	4	2
Occupy Patrol Base	9	3	1.9	20	3	2
Move Tactically	12	3	1.7	23	3	2
Perform Raid	12	4	1.6	29	4	2
Defend	33	4	1.2	61	3	2
Perform Point Ambush	15	4	1.1	28	3	2
Knock Out Bunker	8	4	3.1	20	4	2

to determine if there were 'cutpoints' in the distributions of the attributes where "high" versus "low" distinctions could be made. Consistent 'cutpoint' values for four of the six attributes that were evaluated were found across team types. These were for the following variables:

1. Number of subtasks and standards;
2. Emergent versus established;

3. Coactive-interactive; and

4. Potential for correction or compensation.

For the other two variables, number of sub-teams per subtask and number of individual tasks per collective task, the variability between team types was large enough that different 'cutpoints' for these variables were deemed necessary for different team types. Evaluation of collective tasks representative of a large number of other team types will probably be needed to determine if a single generalizable 'cutpoint' can be found for these two variables.

For all of the 'cutpoints,' the values chosen for classification into "high" and "low" impact are near the medians of the numeric distributions of the attributes. Some minor adjustments away from the median values were made, for convenience and use of round numbers in the classification process. The selected 'cutpoints' for the six attributes are shown in Table 10. The different values used for classifying the two 'problem' factors into "high" and "low" judgments are shown for each team type.

Table 10

'Cutpoints' for Collective Task Attributes

Attribute		Values for 'Low' Range	Values for 'High' Range
Number of Subtasks and Standards		5 or less	More than 5
Established *versus* Emergent Rating		Less than 3	3 or more
Number of Sub-teams per Sub-Task	Armor	1.5 or less	More than 1.5
	Light	2 or less	More than 2
	Mech.	1.5 or less	More than 1.5
Number of Individual Tasks	Armor	Less than 6	6 or more
	Light	Less than 16	16 or more
	Mech.	Less than 29	29 or more
Coactive *versus* Interactive Rating		Less than 3	3 or more
Rating of Potential for Correction or Compensation		Less than 2	2 or more

The "high" and "low" judgments, by attribute, for Light Infantry Platoon collective tasks are shown in Table 11. It is clear from Table 11 that there is substantial variability associated with collective tasks on the attributes in this taxon. The ordering of the tasks with respect to the total sensitivity score also seems to make reasonable sense to one who has studied the tasks.

The "high" and "low judgments for each task on each attribute were combined to develop sensitivity ratings for each of the primary predictors, and these ratings were then summed to give a total sensitivity score for each collective task. These data are presented in Figure 12. Note that, as

Table 11

Impact Ratings on Collective Task Attributes for Light Infantry Platoon Tasks

Task Title	Attributes					
	Number of Subtasks	Established *versus* Emergent	Number of Subteams	Number of Individual Tasks	Coactive *versus* Interactive	Potential for Correction/ Compensat.
Prepare for Chemical Attack	Low	Low	Low	Low	Low	Low
Defend Against Air Attack	High	Low	Low	Low	Low	Low
Cross Nuclear Contaminated Area	Low	Low	High	Low	Low	Low
Maintain Operations Security	Low	Low	Low	High	Low	Low
Prepare for Nuclear Attack	Low	Low	High	Low	Low	Low
Cross Chemically Contaminated Area	Low	High	High	Low	Low	Low
Overwatch/Support by Fire	High	Low	Low	High	Low	Low
Reconnoiter Route	Low	High	Low	High	Low	Low
Perform Helicopter Movement	High	Low	High	Low	Low	Low
Employ Fire Support	High	Low	Low	Low	High	Low
Perform Passage of Lines	Low	Low	High	Low	Low	High
Infiltrate/Exfiltrate	Low	High	High	Low	Low	High
Perform Area Ambush	Low	High	Low	High	Low	High
Reconnoiter Zone	High	High	Low	High	Low	Low
Occupy Objective Rally Point	Low	Low	High	Low	High	High
Occupy Observation Post/ Surveillance	Low	Low	High	Low	High	High
Perform Boat Movement	High	Low	High	Low	Low	High
Conduct Stay-Behind Operation	High	High	Low	High	Low	High
Cross Water Obstacle	High	High	High	Low	High	Low
Clear Buildings	High	High	Low	Low	High	High
Construct Obstacles	High	High	High	Low	High	Low
Breach an Obstacle	High	High	High	Low	High	Low
Occupy Assembly Area	High	Low	Low	High	High	High
Assault	Low	High	High	High	High	Low
Perform Aerial Resupply	High	High	High	Low	High	Low
Perform Link-up	Low	High	High	Low	High	High
Reconnoiter Area	Low	High	High	High	High	Low
Defend a Built-up Area	High	High	Low	High	High	High
Clear Woodline	High	High	High	High	Low	High
Perform Anti-Armor Ambush	Low	High	High	High	High	High
Perform Hasty Ambush	High	High	Low	High	High	High
Clear Trenchline	High	High	Low	High	High	High
Occupy Patrol Base	High	High	Low	High	High	High
Move Tactically	High	High	Low	High	High	High
Perform Raid	High	High	Low	High	High	High
Defend	High	High	Low	High	High	High
Perform Point Ambush	High	High	Low	High	High	High
Knock Out Bunker	High	High	High	High	High	High

predicted by the influences of each attribute, the sensitivity scores for both forgetting and membership change are always the same.

Correlations Among the Factors

To examine the relationships among the factors that make up Taxon 2, correlations between collective tasks' raw scores on the factors were computed. Initially, correlations were computed for each team type separately, and the results examined across team types. This showed that the

Table 12

Impact Ratings on Collective Task Attributes for Light Infantry Platoon Tasks

Task Title	Impact Rating for Forgetting	Impact Rating for Membership Change	Combined Impact Rating
Prepare for Chemical Attack	0	0	0
Defend Against Air Attack	1	1	2
Cross Nuclear Contaminated Area	1	1	1
Maintain Operations Security	1	1	2
Prepare for Nuclear Attack	1	1	2
Cross Chemically Contaminated Area	2	2	4
Overwatch/Support by Fire	2	2	4
Reconnoiter Route	2	2	4
Perform Helicopter Movement	2	2	4
Employ Fire Support	2	2	4
Perform Passage of Lines	2	2	4
Infiltrate/Exfiltrate	3	3	6
Perform Area Ambush	3	3	6
Reconnoiter Zone	3	3	6
Occupy Objective Rally Point	3	3	6
Occupy Observation Post/ Surveillance	3	3	6
Perform Boat Movement	3	3	6
Conduct Stay-Behind Operation	4	4	8
Cross Water Obstacle	4	4	8
Clear Buildings	4	4	8
Construct Obstacles	4	4	8
Breach an Obstacle	4	4	8
Occupy Assembly Area	4	4	8
Assault	4	4	8
Perform Aerial Resupply	4	4	8
Perform Link-up	4	4	8
Reconnoiter Area	4	4	8
Defend a Built-up Area	5	5	10
Clear Woodline	5	5	10
Perform Anti-Armor Ambush	5	5	10
Perform Hasty Ambush	5	5	10
Clear Trenchline	5	5	10
Occupy Patrol Base	5	5	10
Move Tactically	5	5	10
Perform Raid	5	5	10
Defend	5	5	10
Perform Point Ambush	5	5	10
Knock Out Bunker	6	6	12

general patterns of correlations were similar across the three sets of figures. Since this was the case, a stronger test of the possible relationships between or overlaps among the factors could be made by combining the data across team types, and computing correlations across all the collective tasks evaluated. This was done. The resulting correlations are shown in Table 13.

The most interesting information in Table 12 is the relatively high correlations among three of the attributes: the established-emergent rating, the coactive-interactive rating, and the rating of potential for correction or compensation in task performance. While these correlations are not of the same size as those found between Taxon 1 factors, they are large enough to

account for about 25 percent of the variance between each pair of attributes. This indicates that there is probably some overlap in either the concepts behind these attributes, or in the application of the rating scales.

Table 13

Correlations* Among the Six Collective Task Attributes for a Sample of 159 Collective Tasks

	Attributes	2	3	4	5	6
1.	Number of Subtasks	.242	.251	.312	.260	.153
2.	Established-Emergent	---	.002	.181	.550	.523
3.	Number of Sub-teams per Subtask		---	.061	.301	.110
4.	Number of Individual Tasks			---	.264	.134
5.	Coactive-Interactive Rating				---	.512
6.	Potential for Compensation or Correction in Task Performance					---

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* The critical value for *r* for 157 degrees of freedom at the .01 level of confidence is .159 (boldface in table).

Since these correlations are not nearly as large as those found between Taxon 1 attributes, each attribute here is clearly contributing something unique, at least in the manner in which they were evaluated for the collective task descriptions. It is appropriate to keep them as separate attributes for now, particularly since the Taxon 1 attributes with much higher correlations were retained as separate attributes.

While the correlation coefficients are smaller still (but statistically significant), it is interesting to note that the number of subtasks and standards in the collective tasks correlated with all of the other attributes except the potential for compensation or correction in task performance. And, the coactive-interactive rating correlated significantly with all five other attributes. Neither of these were found when the correlations between attributes were computed only within team type.

Validation of Taxon 2 Predictions About Light Infantry Tasks

It was determined that data obtained during Light Infantry unit rotations at the Joint Readiness Training Center (JRTC), Fort Chaffee, AR, could be used to conduct an initial test of the validity of task sensitivity predictions using Taxon 2. The reasoning behind the use of this data is as follows:

1. The task data from JRTC rotations probably represent a sample that is typical of Light Infantry units' training and turnover/turbulence experience. Different levels of task performance, training history,

and membership change in units would be represented in the units participating in JRTC rotations. In one sense, the data from these rotations represent a quasi-random sample of task performance on Light Infantry tasks, obtained under relatively uncontrolled conditions.

2. Being a quasi-random sample of performances, the JRTC data represent an extreme test of the correctness of the predictions of Taxon 2 with respect to tasks. That is, there is a large amount of random variation in the task performance data that cannot be controlled for using data on training history, prior performance, or personnel change—such data are simply not available. In terms of Taxon 2, this means that there will be a distribution of performance on every task that is partly a function of skill decay resulting from time since training and from changes in unit membership.

3. If the predictions from Taxon 2 bear resemblance to the measured performance levels of tasks represented in the JRTC data, then the predictions can be considered at least construct-valid—tasks are at least being ordered by Taxon 2 in a fashion consistent with task performance in a random sample. What this would ultimately mean is that task performance in such a random sample tends to be distributed as though performance from some initial level has changed according to the fashion predicted by Taxon 2. No other conclusions can or should be drawn from such results.

The data on Light Infantry Platoon task performance from eight recent JRTC rotations[2] were obtained by the Army Research Institute (ARI) from the Center For Army Lessons Learned (CALL) at Fort Leavenworth, KS and made available. In fact, all performance data from these rotations for all echelons down to platoon level were included in the data sets provided. Platoon tasks were selected from the larger database for attention, by selecting platoon-specific unit identifiers. Two potential measures of performance were included in the datasets—overall task performance ratings[3] and Training and Evaluation Outline (T&EO) subtask GO-NO GO scores for subtasks which were rated during performance assessment. It was decided to contrast both of these measures with Taxon 2 predictions.

For the subtask GO-NO GO measure, composite variables were constructed from the individual subtask records in the database. This was done by aggregating the subtask scores for a particular task performance from the score records in the database. Two different schemes were used for developing composite performance metrics—an unweighted approach and a criticality-weighted approach.

The unweighted approach simply added the number of valid GO scores for subtasks (some subtasks were not scored in many cases), and divided by the number of subtasks that contributed to the overall score. The weighted approach considered the nature of each subtask (as indicated in the database). In AMTP T&EOs, some subtasks are designated as critical for overall task performance; a NO GO on any such subtask results in an Untrained rating for the entire task performance. Other subtasks are designated as leader subtasks; some few are designated as both leader subtasks and critical. It was decided to attempt to reflect these designations in developing the weighted metric. Accordingly, weights were assigned as follows:

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[2]Rotations 90-02, 90-01, 89-09, 89-08, 89-07, 89-06, 89-05, and 89-02.

[3]On a Trained/Needs Practice/Untrained, or T/P/U scale, as prescribed by ARTEP 7-8-MTP.

1. Subtasks that were designated as neither critical nor leader subtasks were given a weight of 1.

2. Subtasks that were designated as either critical or leader subtasks, but not both, were given a weight of 2.

3. Subtasks that were designated as both critical and leader subtasks were given a weight of 4.

In order to properly reflect the weightings, subtask GO-NO GO data were recoded, such that a NO GO for a subtask was scored as 1 and a GO was scored as 2.

The composite variables were developed on a database that included the combined data for all eight rotations. This was to assure that data on a maximum number of tasks (and as large a sample as possible for each task) would be included in the analysis.

A total of 1285 task performances were included in the databases. The distribution of task performances in the database in shown in Table 14. The distribution of tasks actually used in analysis for the two metrics differed, however. The reason for the differing number of cases for the two metrics is that some cases used in the weighted metric analysis (922 cases or task performances) could not be included in the unweighted metric analysis (795 cases). Some cases were used in neither analysis, for a variety of reasons.

The predictive scores on Taxon 2 were added to the task records in both databases. For some tasks included in the databases, no Taxon 2 predictions are available—information on the tasks was not complete enough to conduct valid analyses of the Taxon 2 factors. Because of the data properties of the Taxon 2 predictive scores, nonparametric analyses were used to assess the agreement of task performance data with the Taxon 2 predictive scores.

Results

Analysis of the overall task training status for the tasks (T/P/U rating) showed no relationship with the predictions from Taxon 2. This is not surprising for several reasons. First, both variables have restricted ranges (1 through 3 for the T/P/U rating in these data; 1 to 12 for Taxon 2 predictions). This normally limits the amount of variability in the joint distributions of the two variables, and thus the ability to statistically detect small differences in subgroups on either variable. Second, the distribution of overall T/P/U ratings for this sample of tasks was negatively skewed (many more tasks rated P and U than rated T); as were the distributions of tasks separated by Taxon 2 predictions. The median of each of the distributions was much higher than the mean. Finally, the overall task training status measure is a summary measure of performance, nominally based on the T&EO GO/NO GO scoring for a task. Thus, it is a condensation of the information available in the T&EO scoring data; variability in performance is reduced by computing this kind of summary measure.

Analysis of the T&EO GO/NO GO scoring data yielded more optimistic and positive results. Median tests (Siegel, 1956) were used to compare the number of cases above and below the median of performance scores for each Taxon 2 prediction category, for both weighted and unweighted measures. Analysis results are presented in Figures 22 (for unweighted performance scores) and 23 (for weighted performance scores).

The trends for analysis of both weighted and unweighted measures is clear. For Taxon 2 prediction categories suggesting lower rates of performance deterioration due to forgetting and membership change, more task

Table 14

Distribution of Tasks in JRTC Platoon Performance Database

Task Name	Frequency	Percent
Helicopter Movement	73	5.7
Perform a Raid	19	1.5
Perform an Ambush	42	3.3
Overwatch/Support by Fire	14	1.1
Disengage*	20	1.6
Perimeter Defense*	60	4.7
Establish a Patrol Base	64	5.0
Passage of Lines (Forward)	44	3.4
Passage of Lines	8	.6
Perform Linkup	37	2.9
Infiltrate/Exfiltrate	31	2.4
Tactical Road March	16	1.2
Occupy an Assembly Area	50	3.9
Breach Obstacles	18	1.4
Assault	53	4.1
Move Tactically	165	12.8
Cross a Danger Area	94	7.3
Reconnoiter Area	16	1.2
Reconnoiter Zone	10	.8
Reconnoiter Route	2	.2
Knock Out Bunker	11	.9
Consolidate/Reorganize	87	6.8
Occupy Obj. Rally Point	25	1.9
Antiarmor Ambush	6	.5
Hasty Ambush	7	.5
Occupy Obs. Post	19	1.5
Employ Fire Support	76	5.9
Construct Obstacles	21	1.6
Sustain*	128	10.0
Perform Area Ambush	7	.5
Perform Aerial Resupply	10	.8
Defend Against Air Attack	5	.4
Maintenance Operations*	47	3.7
Totals	1285	100.0

(Tasks marked with an asterisk do not have Taxon 2 predictions available.)

performances tend to score above the median of the variable metrics than below. Conversely, for Taxon 2 categories suggesting higher rates of performance deterioration, more task performances tend to score below the median than above. For both variables, these results are statistically significant—that is, the proportions of scores above versus below the median in each Taxon 2 category differ from one-half (which would be expected by chance), across categories. And, the proportion of cases above the median tends to become lower as the Taxon 2 category increases.

We interpret this as supporting the construct validity of the predictions made by application of the Taxon 2 factors. Clearly, there is a relationship between the category to which Taxon 2 application assigns tasks and the measured performance level of the tasks as reflected by T&EO scoring.

Median test of:

METRIC Performance metric (Unweighted)
by PREDICT (Taxonomy prediction for task)

METRIC	PREDICT 2	4	6	8	10	12	TOTALS
> Median	1	104	43	72	168	2	390
< Median	3	68	31	72	225	6	405
TOTALS	4	172	74	144	393	8	795

Cases	METRIC Median	Chi-Square	D.F.	Significance
795	.67	20.4723	5	.0010

Figure 22. Median test results for unweighted performance scores

The existence of such a relationship is further reinforced by examining the correlation coefficients between the Taxon 2 category predictions for the tasks and the performance scores. For the unweighted variable, Pearson's r is -.1323 ($df = 915$, $p < .001$); for the weighted variable, r is -.1538 ($df = 920$, $p < .001$). There is thus a statistically significant, although small in absolute terms, relation between Taxon 2 predictions and the performance measures. The negative direction of the coefficients is expected—larger values of the Taxon 2 prediction correspond to overall less proficient performance (and smaller scores on the performance metric).

Median test of:

PERFSCOR (Weighted performance score)
by PREDICT (Taxonomy prediction for task)

PERFSCOR	PREDICT 2	4	6	8	10	12	TOTALS
> Median	3	103	47	74	158	7	402
< Median	2	91	39	112	283	3	520
TOTALS	5	194	86	186	441	10	922

Cases	PERFSCOR Median	Chi-Square	D.F.	Significance
922	1.860	26.4175	5	.0001

Figure 23. Median test results for weighted performance scores

DISCUSSION

Subsequent to the development and initial application of the taxonomy to select tasks for data gathering, some changes occurred in the methods used in the overall project. It was determined that circumstances would make impossible the collection of the needed task performance, stability, and training history data **directly from Army units**. Therefore, an alternate method was developed for obtaining retention estimates for collective tasks. Subject Matter Experts (SMEs) are currently developing estimates of performance decrement in Light Infantry, Mechanized Infantry, and Armor Platoons, and Light Infantry and Mechanized Infantry Squads, based on carefully structured scenarios of time since training and membership change. While SME estimates, particularly of performance, have some well-known limitations, these procedures enable developing a data set from which to make initial estimates and models of collective task retention. These estimates can be further refined as opportunities to gather empirical data from actual units become available.

This change in approach, however, does not reduce the need for the taxonomy. The performance change sensitivity predictions made from applying the taxonomy have use in developing the methodology for predicting collective training needs. The sensitivity predictions will be used to explore relationships among the various retention equations developed from the SME estimate data. If, as is expected, the equation parameters for collective tasks that have roughly the same sensitivity predictions are also similar, composite equations can be developed that predict performance change for **groups** of tasks. This will result in a simpler method than if one equation for each task must be included.

The taxonomy, in its present state, is clearly limited for some purposes. For instance, it presently does not include any assertions about the relative strengths of influence of the various attributes that we believe influence the parameters that cause team performance to deteriorate. This precludes its independent use for any **quantitative** predictions of performance change. However, this may be remedied as data on the patterns of performance change in teams become available. The relative influence of each of the attributes can and will be explored, given the availability of these data. A revised version of the taxonomy may include information about the relative strength of each attribute in its influence on the parameters of team performance change.

The model of collective task performance determinants presented here also has value, independent of its value in developing the taxonomy. Since the model deals in terms of the generic categories of skills and knowledge needed for teams to perform, it may be used as a general framework to structure further thinking about team behavior and performance. This has the potential of providing a frame of reference for integrating the presently chaotic and difficult-to-interpret findings of the larger literature on teams and teamwork. Perhaps future work growing out of this frame of reference will provide a much-needed general theoretical statement about team behavior and performance, to enable the programmatic design of teams for many purposes.

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